APPENDIX A – HARDWARE AND SENSORS

A.1 Dynamometer

A.2 Remote Throttle Control

A.3 0_2 Sensors

A.4 Thermocouples

A.5 Pressure Sensor

A.6 Ambient Temperature and Humidity Monitor

A.7 Hot Wire Anemometer

A.8 Digital Manometer

A.9 Fuel Flow Meter

A.10 DAQ System

A.1 Dynamometer

Kahn 101-80 Dynamometer

PORTABLE GENERAL PURPOSE DYNAMOMETERS

KAHN SERIES
101

KAHN
KAHN INDUSTRIES INC.

KAHN SERIES 101 GENERAL PURPOSE DYNAMOMETERS

FOR LOAD TESTING OF SMALL GAS TURBINES, GASOLINE ENGINES, AUXILIARY POWER UNITS, ELECTRIC AND HYDRAULIC MOTORS, HIGH SPEED GEARBOXES, BELT AND CHAIN DRIVES.

FEATURES

- Easy to install and to operate
- Lightweight, portable units with standard AND 10266/10262 mounting flange
- Hardened stainless steel power elements providing superior resistance to cavitation and corrosion
- Straightforward design permitting quick overhaul
- Spring loaded, precision ball bearings—grease packed or oil mist lubricated
- Water cooled quality carbon face seal
- Built-in 60 tooth gear for use with magnetic speed pickup
- Full power absorption in either direction of rotation

OPERATING PRINCIPLE

A single perforated disc rotates in a housing between perforated stators. Cold water enters the rotor chamber at the center. The water is accelerated by the rotating disc and thrown outwards. From the outer diameter of the rotor chamber inwards, the water forms an annulus which rotates at approximately half of the angular disc speed. The centrifugal pressure resulting from this process, forces the hot water out of the rotor chambers.

Power is absorbed—and converted into heat—by water vortices generated in rotor and stator holes. The resulting drag applies a resistance to rotation and tends, with an equal effort, to turn the dynamometer housing in the trunnion bearings. The housing is restrained from turning by a load cell which is mounted to the torque arm at a fixed distance from the centerline of the dynamometer.

The amount of power absorbed by the dynamometer is a function of water level (size of rotating water annulus) and speed. The water level is modulated with the inlet and outlet control valves. At a given speed, maximum power is absorbed when the rotor chambers are completely filled with water.

WATER SUPPLY REQUIREMENTS

Hydraulic dynamometers convert mechanical energy into heat. The heat is dissipated by a continuous flow of water through the dynamometer. The flow rate is proportional to the amount of power absorbed.

Water Flow*	6 gal/hr hp (30 l/hr kW)
Supply Pressure	50 psig (3.5 bar)
Max. Inlet Temperature	90°F (32°C)
Max. Outlet Temperature	140°F (60°C)
Filtration	40 mesh screen
Seal Water Flow	0.1 gal/min (0.4 l/min)

*at delta t = 50°F (28°C)

ROTOR ASSEMBLY

Single perforated disc mounted on shaft by means of an involute spline. Shaft and disc made from hardened stainless steel. 60-tooth shaft mounted gear. Entire rotor assembly dynamically balanced.

BEARINGS, LUBRICATION AND SEAL

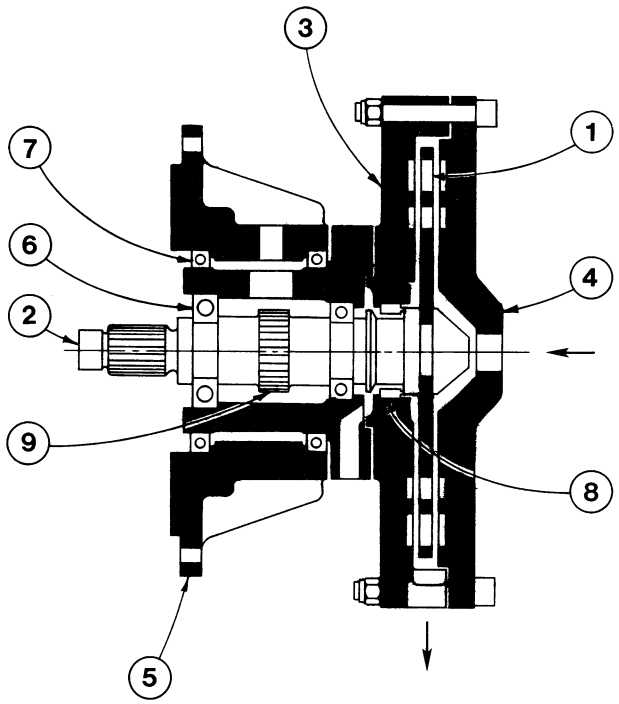
Two ABEC 5 or ABEC 7 precision ball bearings. Spring loaded to reduce vibration. Grease packed or oil mist lubricated. Oil mist lubricated units with one removable oil injector per bearing. Including wall mounted oil mist system with air pressure regulator, filter and lubricator.

Lubricating Oil	MIL-L-7808 or Mobil DTE 24
Oil Reservoir Capacity	19 oz. (.56 l)
Air Requirements	max. 20 scfm dry air
Air Supply Pressure	50-100 psig (3.5-7.0 bar)

Stationary carbon face seal with chrome plated mating ring. Continuously cooled with water to prevent distortion and cracking of the carbon ring. Any water leakage across the carbon face seal is discharged by a rotating flinger into a drain cavity.

HOUSING AND TRUNNION MOUNT

Lightweight aluminum housing supported by two grease packed trunnion bearings. Trunnion mount with AND 10266/10262 mounting flange. Rotor chamber lined with hardened stainless steel stator plates. Built-in vacuum breaker to maintain atmospheric pressure in the rotor chamber.



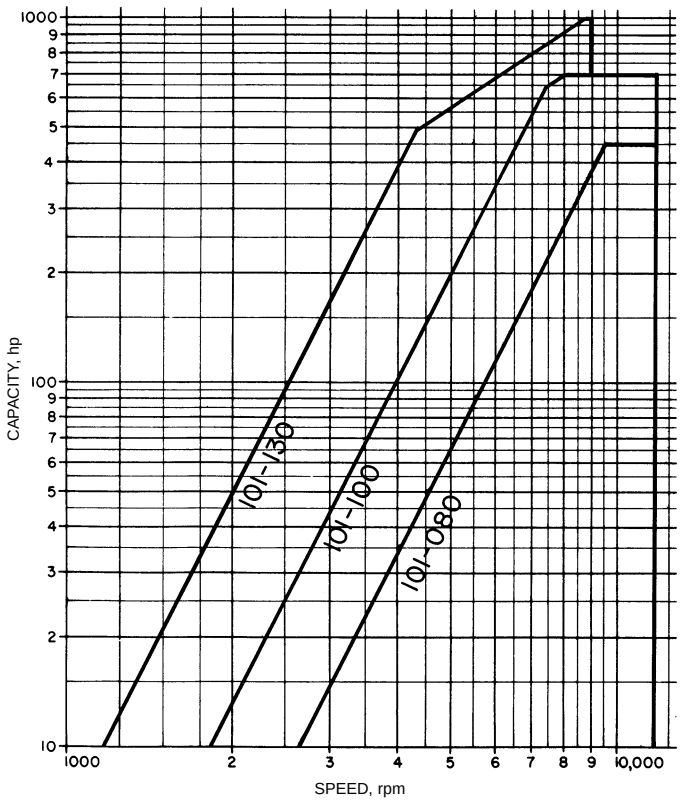
1 Perforated Disc Rotor
2 Shaft
3 Housing
4 Endcap
5 Trunnion Mount
6 Shaft Bearings
7 Trunnion Bearings
8 Carbon Face Seal
9 60-tooth Gear

SERIES 101
GENERAL PURPOSE DYNAMOMETERS

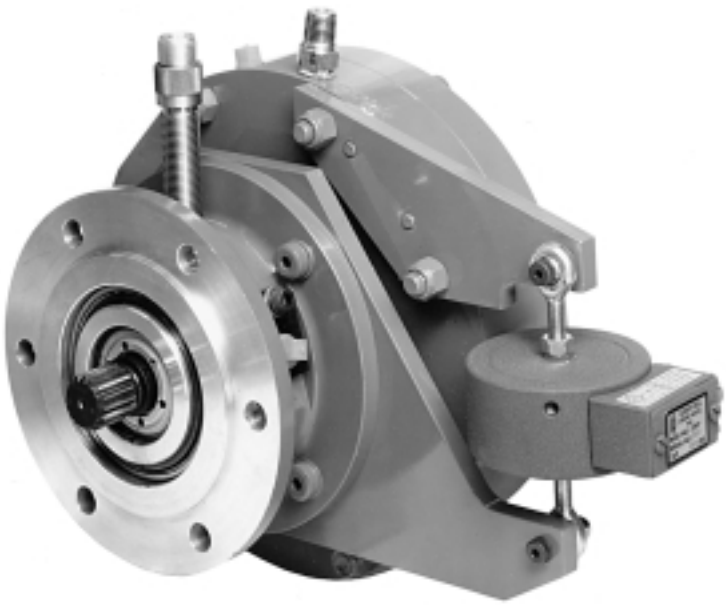
SPECIFICATIONS

Model	Max. Power hp	Max. Speed rpm	Max. Torque ft.lb.	WR² in²lb	Dry Weight lbs
101-080	450	14,000	250	21	50
101-100	700	11,500	450	57	60
101-130	1000	9,000	600	180	85

OPERATING RANGE



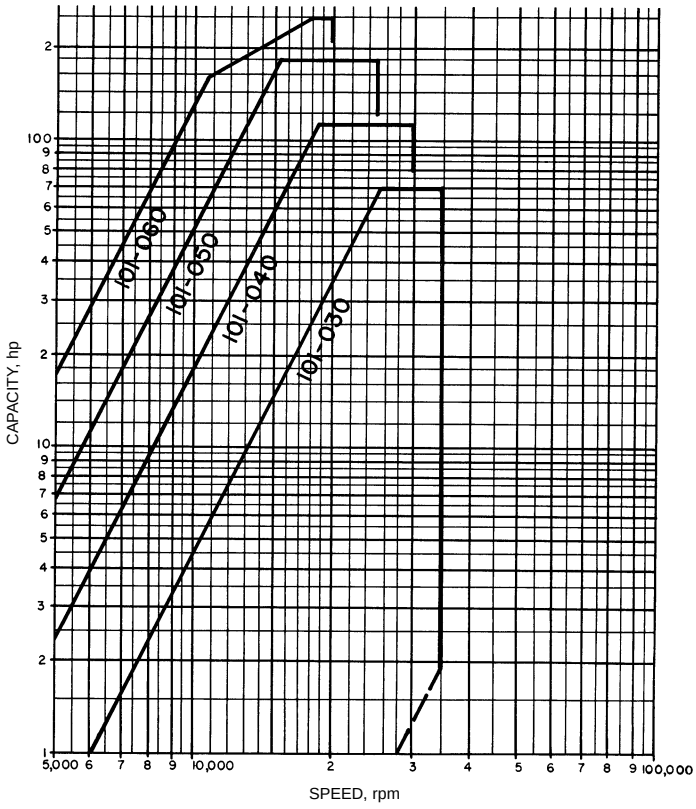
SERIES 101
HIGH SPEED DYNAMOMETERS

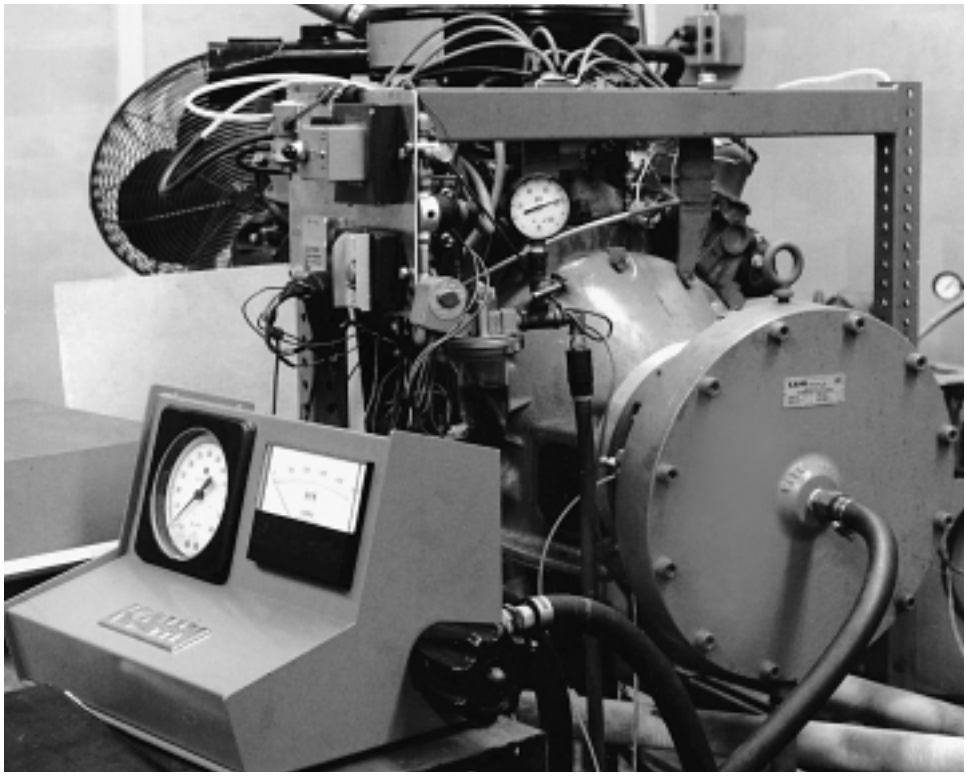


SPECIFICATIONS

Model	Max. Power hp	Max. Speed rpm	Max. Torque ft.lb.	WR² in²lb	Dry Weight lbs
101-030	70	35,000	14.7	2.9	23
101-040	110	30,000	32	3.3	23
101-050	180	25,000	60	4.5	23
101-060	250	20,000	75	6.1	23

OPERATING RANGE





Model 101-130 dynamometer mounted to Chrysler 318 cu. in., V-8 gasoline engine. Control console Series 513 shown in foreground.

LOAD CONTROL SYSTEM SERIES 513

Portable control console with built-in 4½″ torque gage, self-powered analog speed indicator and water inlet control valve. Torque is measured by a hydraulic load cell (compression only). Magnetic speed pickup, outlet valve, seal water valve. Connecting cables 10 feet (3.0m) long. Filled with hydraulic fluid and calibrated in the factory. Standard ranges 600 ft. lb/10,000 rpm. System accuracy: ± 2% F.S. for torque and ± 1% F.S. for speed.

CALIBRATION SYSTEM SERIES 504

Including calibration arm 36″ long, weight hanger, adjustable counter weight. Max. ten slotted weights 20 lbs each per National Bureau of Standards, Class C.

DIGITAL READOUT SYSTEM SERIES 511

Portable instrument console 9½″ wide with digital display of torque and speed. Built-in strain gage conditioner with mV/V reference standard. Calibrated in in. lb., ft. lb., Kgm or Nm. Easy to recalibrate. Universal strain gage load cell (tension and compression), magnetic speed pickup, connecting cables 30 feet (9.14m) long. Power requirements 120V, 50/60 Hz, 35 Watts. System accuracy ± 0.2% F.S. for torque and ± 0.1% F.S. for speed. In conjunction with Series 503 pneumatic control valves.

No. 1799A Printed in U.S.A.

KAHN

KAHN INDUSTRIES INC. 885 Wells Road, Wethersfield, CT 06109 Phone: (203) 529-8643 Telex: 9-9301

A.2 Remote Throttle Control

Dynesystems DTC-1 Digital Throttle Controller

DTC-1
Digital Throttle Controller
User's Manual

Revised November 2001

© 2001 Dyne Systems Co., LLC All Rights Reserved

DyneSystems Co.
Contact Information

Shipping Address:
W209 N17391 Industrial Drive
Jackson, WI 53037

Mailing Address:
P.O. Box 18
Jackson, WI 53037

Toll Free Phone:
(800)657-0726

Fax:
(262)677-9308

Web:
www.dynesystems.com

No part of this manual may be reproduced or transmitted in any form or by any means, including photocopying, recording, or using information storage and retrieval systems, for any purpose other than the purchaser's own use, without the express written permission of Dyne Systems Co., LLC.

©2001 by Dyne Systems Co., LLC. All Rights Reserved.

Any other product names and services identified in this manual are trademarks or registered trademarks of their respective owners. No such uses, or the use of any trade name, is intended to convey endorsement or other affiliation with Dyne Systems Co., LLC.

Revision History

Item #: MAN-DTC1-00001

May, 2001
Initial Version

Table of Contents

Chapter 1 – Specifications

Specifications 1-1
- Control Enclosure 1-1
- Control Output 1-1
- Environmental 1-1
- Power Fail Protection 1-2
- Actuator Assembly 1-2
- Actuator Stroke 1-2
- Closed Loop Control 1-2
- Function Keys 1-2
- Remote Operators' Control 1-2
- Computer Control 1-3
- Dyn-Loc Basic 1-3
- Auxiliary I/O 1-3
- Fault Control 1-3

Chapter 2 – Installation Instructions

- Signal Wiring 2-1
- MS Connectors General Information 2-1
- Sub-D Type Connectors General Information 2-1
- 120 VAC Power 2-2
- Mechanical Installation of the Actuator 2-2
- Connecting the DTC to the Actuator 2-2
- Connecting the Remote DTC 2-4
- Connecting the DTC to the Dyn-Loc 2-4
- Connecting for Stand-Alone Operation 2-4
  - DS303C DIP Switch Settings 2-4

Chapter 1

Specifications

1.0 Introduction

The DTC-1 controls throttle position, RPM, TQ, MAP, or manifold vacuum to ±1 unit accuracy, providing zero regulation and drift of digital setpoints. 16 sets of PID parameters allow the DTC-1 to be adjusted to variations in engine under test or in engine operating point. Teamed with Dyne Systems' Dyn-Loc IV dynamometer controller, all provisions are made for reference and feedback data, instrumentation, and automation control. The DTC-1 may also be used in a stand-alone situation.

2.0 Specifications

2.1 Control Enclosure

- Dimensions: 19" x 7" x 13" rack or bench mounted enclosure.
- Weight: 20 pounds.
- Input Power: 120VAC @ 1 amp.

2.2 Control Output

±20VDC @ 3A max., Actuator Servo Motor drive. Amplifier has instantaneous current limit, and over temperature shutdown. Digital Encoder Excitation: +5VDC @ 50 ma. This feeds only Dyn-Loc's actuator which is considered part of the DTC-1.

2.3 Environmental

- +10 to +40 DegC ambient temperature range.
- Humidity to 95%, non-condensing.

2.4 Power Fail Protection

NICAD battery-backed DC. DC power supplies allow throttle return to idle and orderly system shutdown.

2.5 Actuator Assembly

- Housing Dimensions: 8"L x 3-1/4"D x 3/8" Wall cylinder.
- Foot mounted, 3-1/2" x 2" bolt pattern.
- Drip Proof for Wash-Down protection.
- Actuator: DC Servo Motor/Gearhead/Encoder assembly.

2.6 Actuator Stroke

- Maximum Stroke Length: 4".
- Minimum Stroke Length: 1".
- Maximum Stroke Angle: 70º.
- Maximum Stroke Torque: 2.5 lb-ft. (standard), 5.00 lb-ft. and 10.00 lb-ft. (optional).

2.7 Closed Loop Control

- Highly adaptive, optimum response for all engine conditions.
- Position control, digital, to 0.1% of stroke.
- Torque control, digital to 10,000 lb-ft.
- RPM control, digital, to 25,000 RPM. (Programmable PPR Factor)
- Manifold vacuum: 0 to 29 In. Hg. or MAP control: 0 to 150.00 kpa.
- 0% regulation and drift from set-point.
- RPM and torque feedback, and logic signals available from Dyn-Loc, or customer sources.
- Closed loop control coefficients programmable in setup mode, 16 sets.

2.8 Function Keys

Four programmable function keys may be used from Dyn-Loc basic programs or as Dyne Systems customized keys.

2.9 Remote Operators' Control

- In 7" x 9" x 4" Nema 12 enclosure.
- Provides upper and lower limit set-up, jog PB, and DTC soft shutdown.

2.10 Computer Control

- Programming language: Dyn-Loc Basic.
- Computer control over RS232 serial link, with or without the Dyn-Loc IV control.
- Serial link parameters are settable in DTC setup mode.
- Automatic stand-alone control using internal battery ram 64K NVRAM.
- Analog reference option includes parallel mode control.

2.11 Dyn-Loc Basic

Programs may be downloaded over serial link at up to 19.2K baud for stand-alone operation.

2.12 Auxiliary I/O

- Customer emergency stop input.
- Customer soft shutdown (close throttle) input logic.
- Analog feedback input, may be used for torque or RPM feedback.
- Magnetic pickup input.
- Analog reference input, 0 to +10VDC; 12 bit conversion, optional card.
- 8 bit digital I/O to DS302 PCB: optical logic/power control, optional card.
- Buffered expansion bus for new/custom I/O.
- 0 to +10 VDC analog output representing actuator position, optional card (can be used for electronic throttles).

2.13 Fault Control

- All fault conditions (except amplifier over-temperature) serviced with HELP screen.
- Software stall detection and shutdown, prevents motor damage.
- All critical device connectors interlocked.
- Unloaded engine overspeed trip programmable RPM.
- Dyno control/DTC mode conflicts are trapped and displayed.

A.3 0_2 Sensors

Bosch Lambda Sensor LSU 4.9

ETAS ES430 Lambda Module

Lambda Sensor LSU 4.9

This sensor is designed to measure the oxygen content and λ-value of exhaust gases in automotive engines (gasoline or Diesel).

The wide band lambda sensor LSU 4.9 is a planar ZrO_2 dual cell limiting current sensor with integrated heater. Its monotonic output signal in the range of λ = 0,65 to air makes the LSU capable of being used as an universal sensor for λ = 1 measurement as well as for other λ ranges. The connector module contains a trimming resistor, which defines the characteristic of the sensor. The LSU operates only in combination with a special LSU-IC, used in most Bosch Motorsport ECUs and lambda control boxes (LT4).

Application	
Application	0,65 ... ∞
Fuel	Fuel/Diesel
Exhaust Gas Pressure	< 4 bar
Exhaust Gas Temperature Range (Operating)	< 930 °C
Exhaust Gas Temperature Range (Maximum)	< 1030 °C
Hexagon Temperature	< 600 °C
Cable and protective Sleeve Temperature	< 250 °C
Connector Temperature	< 140 °C
Storage Temperature Range	-40 ... 100 °C
Max. Vibration (stochastic peak level)	< 100 g

Mechanical Data	
Weight w/o Cable	120 g
Length	84 mm
Thread	M18 x 1,5
Wrench Size	22 mm
Tightening Torque	40 ... 60 Nm

Electrical Data	
Power Supply H+ Nominal	7,5 V
System Supply Voltage H+ (min)	10,8 V
Heater Power steady state	7,5 W
Heater Control Frequency	≥ 100 Hz
Nominal Resistance of Nernst Cell	300 Ohm
Max Current load for Nernst Cell	250 µA

Connectors and Cables	
Connector	AS 6-07-35PN
Connector Loom	AS 6-07-35SN
Pin 1	Uh+
Pin 2	Uh-
Pin 3	APE
Pin 4	IPN
Pin 5	RE
Pin 6	R
Sleeve	Fiber Glas / Silicone coated
Cable Size	22
Cable Length L	30 ... 100 cm

Application Hint

The LSU4.9 can be connected to all Bosch Motorsport ECUs (MS 4, MS 5, MS 15) and lambda control units like LT4.

The lambda sensor should be installed at point which permits the measurement of a representative exhaust-gas mixture, which does not exceed the maximum permissible temperature.

Install at a point where the gas is as hot as possible.

Observe the maximum permissible temperature.

As far as possible install the sensor vertically (cable upwards).

The sensor is not to be fitted near to the exhaust pipe outlet, so that the influence of the outside air can be ruled out.

The exhaust-gas passage opposite the sensor must be free of leaks in order to avoid the effects of leak-air.

Protect the sensor against condensation water.

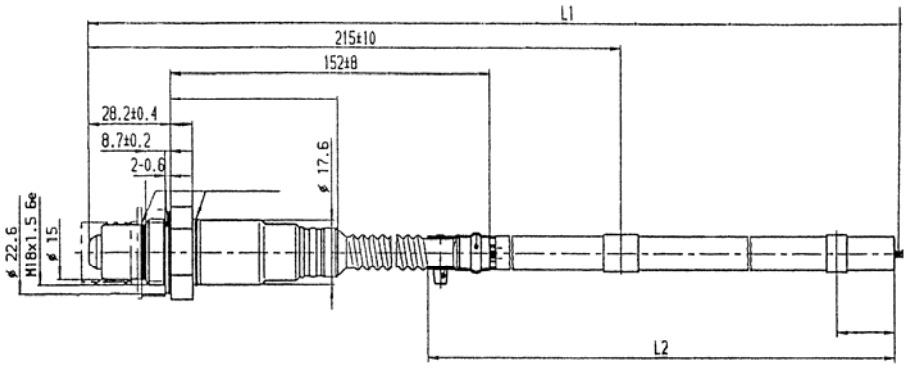
The sensor is not to be painted, nor is wax to be applied or any other forms of treatment. Use only the recommended grease for lubricating the thread.

Please find further application hints in the offer drawing (http://www.bosch-motorsport.com).

Characteristic	
Signal Output	Ip meas / Ua (AWS)
Accuracy @ lambda = 1	1,016 +/- 0,007
Accuracy @ lambda = 0,8	0,80 +/- 0,01
Accuracy @ lambda = 1,7	1,70 +/- 0,05

IP	UA [V]	Lambda
-1,243	0,192	0,750
-0,927	0,525	0,800
-0,800	0,658	0,822
-0,652	0,814	0,850
-0,405	1,074	0,900
-0,183	1,307	0,950
-0,106	1,388	0,970
-0,040	1,458	0,990
0,000	1,500	1,003
0,015	1,515	1,010
0,097	1,602	1,050
0,193	1,703	1,100
0,250	1,763	1,132
0,329	1,846	1,179
0,671	2,206	1,429
0,938	2,487	1,701
1,150	2,710	1,990
1,385	2,958	2,434
1,700	3,289	3,413
2,000	3,605	5,391
2,150	3,762	7,506
2,250	3,868	10,119

Part Number	
LSU 4.9	**B 261 209 356**



ES430
Lambda Module

Functions at a Glance

- Supports LSU 4.9 Lambda Sensor
- Measures lambda, 1/lambda, air-fuel ratio, fuel-air ratio, oxygen content, and pump current
- Linearized analog output
- Easily configurable to support different fuels or combustion types
- Automatic detection of sensor or wiring failures
- Operating temperature from -40 °C to 120 °C (-40 °F to 248 °F)
- Rugged waterproof and dustproof housing (IP67)
- Very small form factor and smart stacking concept
- Scalable daisy chained measurement setups
- Open protocol (XCP-on-Ethernet)

ETAS Group
Automotive LifeCycle
Solutions

Rugged Lambda Measurement

The robust ES430 Lambda Module has been designed to be installed in close proximity to the lambda sensor. The ES430 is capable of withstanding the environmental conditions which are typical for exhaust system installations.

The ES430 Lambda Module provides lambda (λ) as well as 1/λ, air-fuel ratio (A/F), fuel-air ratio (F/A), oxygen content (O_2), and pump current (Ip) measurements through the use of the Bosch LSU 4.9 lambda sensor. The measurement values are calculated from the sensor signal using a sensor- and combustion-specific characteristic curve (linearization). The sampling rate of the signal is software configurable in the range from 0.5 Hz to 2 kHz. The ES430 provides the host system with multiple types of digital measurement signals simultaneously. In addition, one linearized signal can be put out as analog voltage. The ES430 operates the LSU 4.9 sensor at a constant temperature to ensure measurement accuracy. To prevent damage or degradation of the sensor element, the ES430 provides for heating of the λ sensor even during standby mode. Standby is automatically entered when the module is disconnected from the host PC application.

In addition, a mechanism is provided to identify the type of sensor connected via the splitter cable. This eliminates potential errors due to the use of incorrect characteristic parameters.

Open Integration

The standardized XCP-on-Ethernet protocol is used for data transfer. Configuration and integration tools provide for an easy integration of the ES430 Lambda Module into measurement and development tools. A LabVIEW® driver as well as a C-based library are available for integration into software applications that don't provide any XCP-on-Ethernet driver functionality.

Time-Synchronous Data

The 100 Mbit/s Ethernet link can transfer measurement data from several ES400 modules with a sampling rate of up to 10 kHz. All modules in a measuring system – whether an ES400 chain, multiple ES400 chains, or a configuration including ES600 measurement modules – are synchronized with an accuracy of 1 µs. In combination with an ETAS ECU and bus interface such as an ES590 module, Lambda sensor and ECU data can be acquired easily and synchronized accurately.

Technical Data[1]

Item	Characteristics	Features
General	Dimension (HxWxD)	51 x 40 x 139 mm / 2.0 x 1.6 x 5.5 in 37 x 40 x 124 mm / 1.5 x 1.6 x 4.9 in (tapered rear)
	Weight	350 g / 0.77 lb
Environment	Temperature range	-40 °C to +120 °C (-40 °F to +248 °F) (operation) -40 °C to +125 °C (-40 °F to +257 °F) (storage)
	Protection class	IP67 (with cables connected)
	Altitude	Up to 5000 m / 16,400 ft
	Tested for	Mechanical shock, vibration, fall, temperature shock, temperature alteration, storage in humidity, salt fog attack, impact from flying rocks, according to DIN EN 60068 res. ISO 16750
Power supply	Operating voltage	5 V to 50 V DC (-40 °C .. 85 °C), 6 V to 50 V DC (+85 °C .. 120 °C)
	Power consumption (at 12 V)	2.0 W typ. (operation), 200 mW typ. (standby)
Host interface	Connection and protocol	100 Mbit/s Base-T Ethernet, Full-Duplex required, XCP-on-UDP/IP
	IP address	Dynamic via INCA or config. tool (default 192.168.40.44)
	Measurement signal types (signals can be provided concurrently to host system for each input channel)	Lambda (λ), 1/λ, air-fuel ratio (A/F), fuel-air ratio (F/A), oxygen content (O_2), and pump current of the λ sensor (Ip). For diagnostic purposes: internal resistance of the λ sensor (R_i)
Sensor connection	Channels	1
	Supported sensor types	Robert Bosch LSU 4.9, automatically detected via splitter cable
	Sensor connection	RB150, Code 1
	Sampling rate	0.5 Samples/s to 2 kSamples/s, R_i is measured with 2 Samples/s
	Heater control	Included; configurable to keep sensor in operation also in module standby mode
	Measurement range	λ: 0.6 to 16 1/λ: 1.67 to 0.0625 A/F: 8.5 to 200 F/A: 0.118 to 0.005 O_2: 0 % to 25 % Ip: -2.5 mA to 5 mA R_i: 0 Ohm to 1950 Ohm
Analog output	Channels	1, electrically isolated to any supply
	Range	0 V to 10 V
	Signal types	λ, 1/λ, A/F, F/A, O_2, or Ip, configurable by software
	Output impedance	Virtually 0 Ohm, short-circuit protected against external voltage of up to 28 V
Software	Supported by INCA V5.4.1 and up via add-on (part of ES430 delivery), INTECRIO V3.x, ES400 configuration and integration tool for XCP applications, C-based library available for integration into software applications that don't provide any XCP-on-Ethernet driver functionality, LabVIEW® driver (Q1/2008).	

Ordering Information

Order Name	Short Name	Order Number
Lambda Module (1-CH)	ES430.1	F-00K-105-922
Optional Accessories		
Lambda Sensor Cable for LSU4.9 with RB150 Plug Code 1, with analog output connector, (22mc-6fc), 3 m/ 9.8 ft	CBAL451.1-3	F-00K-105-926
Lambda Sensor Cable for LSU4.9 with RB150 Plug Code 1, without analog output connector, (22mc-6fc), 3 m/ 9.8 ft	CBAL452.1-3	F-00K-106-127
Lambda Sensor LSU4.9, SR4	LSUS_49	0-258-017-025
Cap to protect unused Souriau sockets	CAP_SOURIAU_8STA	F-00K-105-303

For ES400 system cables and accessories, please refer to the ETAS Product and Service Catalog.

[1] Technical Data are rated for 25 °C unless otherwise noted. All accuracy specifications valid for the first year after delivery.

Contact addresses

ETAS GmbH
70469 Stuttgart, Germany
Phone +49 711 89661-0
Fax +49 711 89661-106
sales.de@etas.com

ETAS S.A.S.
94588 Rungis Cedex, France
Phone +33 1 56 70 00 50
Fax +33 1 56 70 00 51
sales.fr@etas.com

ETAS Ltd.
Burton-upon-Trent
Staffordshire DE14 2WQ
Great Britain
Phone +44 1283 54 65 12
Fax +44 1283 54 87 67
sales.uk@etas.com

ETAS Inc.
Ann Arbor, MI 48103, USA
Phone +1 888 ETAS INC
Fax +1 734 997-9449
sales.us@etas.com

ETAS K.K.
Yokohama 220-6217, Japan
Phone +81 45 222-0900
Fax +81 45 222-0956
sales.jp@etas.com

ETAS Korea Co., Ltd.
Seoul 137-889, Korea
Phone +82 2 57 47-016
Fax +82 2 57 47-120
sales.kr@etas.com

ETAS (Shanghai) Co., Ltd.
Shanghai 200120, P.R. China
Phone +86 21 5037 2220
Fax +86 21 5037 2221
sales.cn@etas.com

ETAS Automotive India Pvt. Ltd.
Bangalore, Karnataka
560 068 India
Phone +91 80 4191 2585
Fax +91 80 4191 2586
sales.in@etas.com

www.etas.com

ETAS/MKT61_Sar/02.2008

A.4 Thermocouples

Omega 5TC Ready-made Insulated Thermocouples

Ready-Made Insulated Thermocouples
with Stripped Leads

ANSI color code shown | To order IEC color code see page A-9

Custom Lengths, Insulations, and Configurations Available

- Available from Stock in Convenient 5-Packs
- PFA, Kapton®, or Glass Braid Insulation
- 20, 24, 30, 36 and 40 AWG Wires
- 1 and 2 m (40 and 80") Lengths Standard
- NIST Calibration Available
- OEM Quantities Available

MEETS OR EXCEEDS SPECIAL LIMITS OF ERROR (SLE) AND EN 60584-2: Tolerance Class 1

"TT" PFA insulation

"GG" Glass braid insulation

Also Available TAP Adhesive Labels!

Thermocouple Adhesive Labels secure wire probes to surfaces. **TAP** adhesive labels have a thickness of 0.064 mm (0.0022") and can be used at a maximum temperature of 180°C (356°F). They are made of a polymide film with a silicone pressure sensitive adhesive.

Please see page F-16 for additional details and ordering information.

Model TAP, roll of 100 adhesive labels, $28, shown smaller than actual size.

MOST POPULAR MODELS HIGHLIGHTED!

Fine 40-Gage PFA Wire | KAPTON® Insulation

To Order *(Specify Model Number)*

Model No. ANSI Color Code	AWG Gage	Diameter mm (in)	Insulation	Price, Pack of 5	
				1 m (40")	2 m (80")
5TC-GG-(*)-20-(**)	20	0.81 (0.032")	Glass Braid	$39	$49
5TC-GG-(*)-24-(**)	24	0.51 (0.020")	Glass Braid	33	43
5TC-GG-(*)-30-(**)	30	0.25 (0.010")	Glass Braid	33	43
5TC-TT-(*)-20-(**)	20	0.81 (0.032")	PFA	50	70
5TC-TT-(*)-24-(**)	24	0.51 (0.020")	PFA	39	49
5TC-TT-(*)-30-(**)	30	0.25 (0.010")	PFA	44	64
5TC-TT-(*)-36-(**)	36	0.13 (0.005")	PFA	50	70
5TC-TT-(*)-40-(**)	40	0.08 (0.003")	PFA	60	80
5TC-KK-(*)-20-(**)	20	0.81 (0.032")	Kapton®	71	99
5TC-KK-(*)-24-(**)	24	0.51 (0.020")	Kapton®	55	69
5TC-KK-(*)-30-(**)	30	0.25 (0.010")	Kapton®	85	113

** Insert calibration J, K, T, or E. ** Specify length, insert "36" for 1 m or "72" for 2 m length.*

Note: *For GG or TT wire, add **$5** per additional 300 mm (12") per package of 5. For KK wire, add **$8** per additional 300 mm (12") per package of 5.*

Ordering Example: 5TC-TT-K-36-36**, 5 each, PFA insulated thermocouples, Type K calibration (CHROMEGA®-ALOMEGA®), 36 AWG, 1 m (40") long, stripped lead termination, **$50.

A.5 Pressure Sensor

Motorola MPX4115A Integrated Silicon Pressure Sensors

Integrated Silicon Pressure Sensor for Manifold Absolute Pressure, Altimeter or Barometer Applications On-Chip Signal Conditioned, Temperature Compensated and Calibrated

MPX4115A
MPXA4115A
SERIES

INTEGRATED PRESSURE SENSOR
15 to 115 kPa (2.2 to 16.7 psi)
0.2 to 4.8 Volts Output

Motorola's MPX4115A/MPXA4115A series sensor integrates on–chip, bipolar op amp circuitry and thin film resistor networks to provide a high output signal and temperature compensation. The small form factor and high reliability of on–chip integration make the Motorola pressure sensor a logical and economical choice for the system designer.

The MPX4115A/MPXA4115A series piezoresistive transducer is a state–of–the–art, monolithic, signal conditioned, silicon pressure sensor. This sensor combines advanced micromachining techniques, thin film metallization, and bipolar semiconductor processing to provide an accurate, high level analog output signal that is proportional to applied pressure.

Figure 1 shows a block diagram of the internal circuitry integrated on a pressure sensor chip.

Features

- 1.5% Maximum Error over 0° to 85°C
- Ideally suited for Microprocessor or Microcontroller–Based Systems
- Temperature Compensated from –40° to +125°C
- Durable Epoxy Unibody Element or Thermoplastic (PPS) Surface Mount Package

Application Examples

- Aviation Altimeters
- Industrial Controls
- Engine Control
- Weather Stations and Weather Reporting Devices

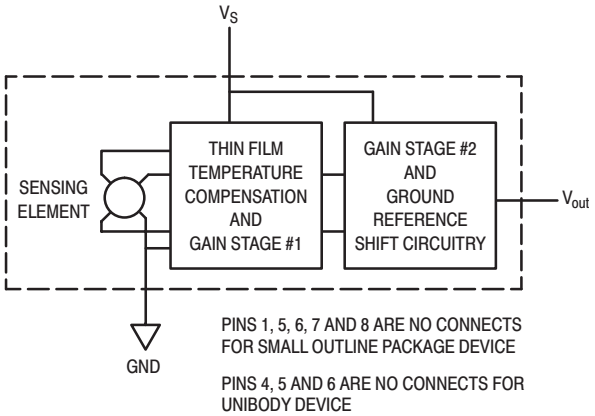
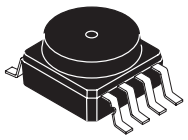
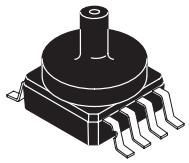

V_S
SENSING ELEMENT
THIN FILM TEMPERATURE COMPENSATION AND GAIN STAGE #1
GAIN STAGE #2 AND GROUND REFERENCE SHIFT CIRCUITRY
V_{out}
GND
PINS 1, 5, 6, 7 AND 8 ARE NO CONNECTS FOR SMALL OUTLINE PACKAGE DEVICE
PINS 4, 5 AND 6 ARE NO CONNECTS FOR UNIBODY DEVICE

Figure 1. Fully Integrated Pressure Sensor Schematic

SMALL OUTLINE PACKAGE



MPXA4115A6U
CASE 482

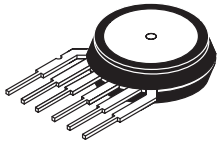


MPXA4115AC6U
CASE 482A

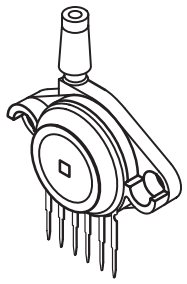
PIN NUMBER			
1	N/C	5	N/C
2	V_S	6	N/C
3	Gnd	7	N/C
4	V_{out}	8	N/C

NOTE: Pins 1, 5, 6, 7, and 8 are internal device connections. Do not connect to external circuitry or ground. Pin 1 is noted by the notch in the lead.

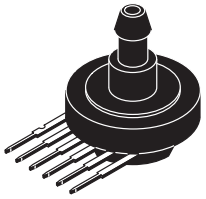
UNIBODY PACKAGE



MPX4115A
CASE 867



MPX4115AP
CASE 867B



MPX4115AS
CASE 867E

PIN NUMBER			
1	V_{out}	4	N/C
2	Gnd	5	N/C
3	V_S	6	N/C

NOTE: Pins 4, 5, and 6 are internal device connections. Do not connect to external circuitry or ground. Pin 1 is noted by the notch in the lead.

REV 4

© Motorola, Inc. 2001

Freescale Semiconductor, Inc.

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

MAXIMUM RATINGS(NOTE)

Parametrics			Units
Maximum Pressure (P1 > P2)	P_{max}	400	kPa
Storage Temperature	T_{stg}	–40° to +125°	°C
Operating Temperature	T_A	–40° to +125°	°C

NOTE: Exposure beyond the specified limits may cause permanent damage or degradation to the device.

OPERATING CHARACTERISTICS (V_S = 5.1 Vdc, T_A = 25°C unless otherwise noted, P1 > P2. Decoupling circuit shown in Figure 3 required to meet Electrical Specifications.)

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range		P_{OP}	15	—	115	kPa
Supply Voltage(1)		V_S	4.85	5.1	5.35	Vdc
Supply Current		I_o	—	7.0	10	mAdc
Minimum Pressure Offset(2) @ V_S = 5.1 Volts	(0 to 85°C)	V_{off}	0.135	0.204	0.273	Vdc
Full Scale Output(3) @ V_S = 5.1 Volts	(0 to 85°C)	V_{FSO}	4.725	4.794	4.863	Vdc
Full Scale Span(4) @ V_S = 5.1 Volts	(0 to 85°C)	V_{FSS}	4.521	4.590	4.659	Vdc
Accuracy(5)	(0 to 85°C)	—	—	—	±1.5	$\%V_{FSS}$
Sensitivity		V/P	—	45.9	—	mV/kPa
Response Time(6)		t_R	—	1.0	—	ms
Output Source Current at Full Scale Output		I_{o+}	—	0.1	—	mAdc
Warm–Up Time(7)		—	—	20	—	ms
Offset Stability(8)		—	—	±0.5	—	$\%V_{FSS}$

NOTES:
1. Device is ratiometric within this specified excitation range.
2. Offset (V_{off}) is defined as the output voltage at the minimum rated pressure.
3. Full Scale Output (V_{FSO}) is defined as the output voltage at the maximum or full rated pressure.
4. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
5. Accuracy is the deviation in actual output from nominal output over the entire pressure range and temperature range as a percent of span at 25°C due to all sources of error including the following:
   - Linearity: Output deviation from a straight line relationship with pressure over the specified pressure range.
   - Temperature Hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure Hysteresis: Output deviation at any pressure within the specified range, when this pressure is cycled to and from minimum or maximum rated pressure at 25°C.
   - TcSpan: Output deviation over the temperature range of 0° to 85°C, relative to 25°C.
   - TcOffset: Output deviation with minimum pressure applied, over the temperature range of 0° to 85°C, relative to 25°C.
6. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
7. Warm–up Time is defined as the time required for the product to meet the specified output voltage after the pressure has been stabilized.
8. Offset Stability is the product's output deviation when subjected to 1000 cycles of Pulsed Pressure, Temperature Cycling with Bias Test.

MECHANICAL CHARACTERISTICS

Characteristics	Typ	Unit
Weight, Basic Element (Case 867)	4.0	grams
Weight, Small Outline Package (Case 482)	1.5	grams

Freescale Semiconductor, Inc.

ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

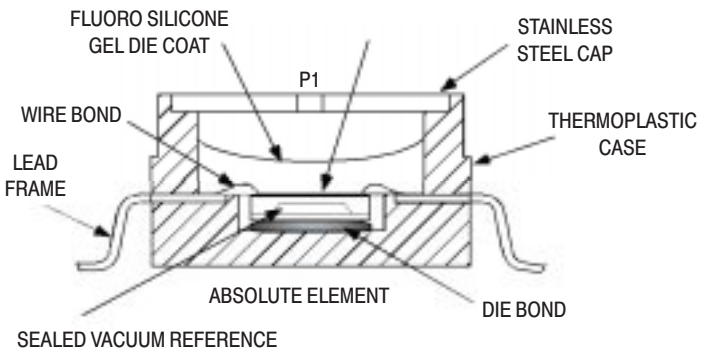


Figure 2. Cross Sectional Diagram SOP (not to scale)

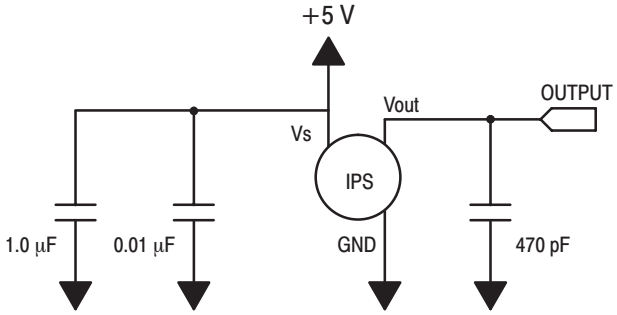


**Figure 3. Recommended power supply decoupling and output filtering.
For additional output filtering, please refer to Application Note AN1646.**

Figure 2 illustrates the absolute sensing chip in the basic chip carrier (Case 482).

Figure 3 shows the recommended decoupling circuit for interfacing the output of the integrated sensor to the A/D input of a microprocessor or microcontroller. Proper decoupling of the power supply is recommended.

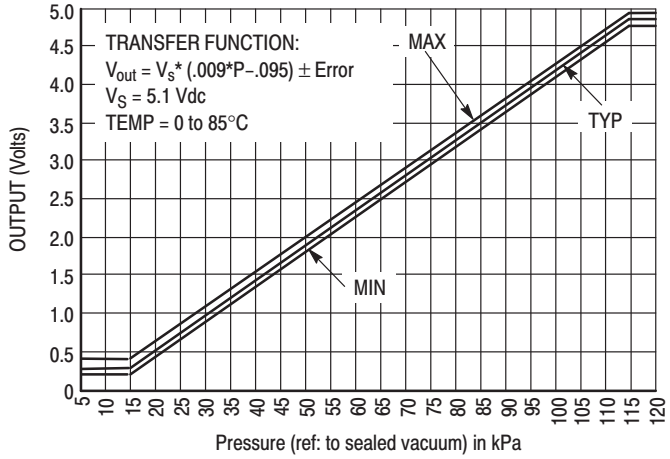


Figure 4. Output versus Absolute Pressure

Figure 4 shows the sensor output signal relative to pressure input. Typical minimum and maximum output curves are shown for operation over 0 to 85°C temperature range. The output will saturate outside of the rated pressure range.

A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the silicon diaphragm. The MPX4115A/MPXA4115A series pressure sensor operating characteristics, internal reliability and qualification tests are based on use of dry air as the pressure media. Media other than dry air may have adverse effects on sensor performance and long–term reliability. Contact the factory for information regarding media compatibility in your application.

Freescale Semiconductor, Inc.

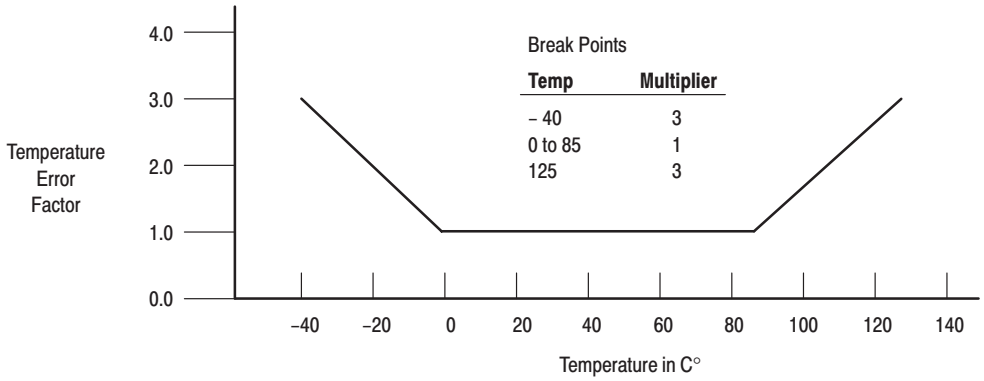
Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

Transfer Function (MPX4115A, MPXA4115A)

Nominal Transfer Value: $V_{out} = V_S \times (0.009 \times P - 0.095)$
$\pm$ (Pressure Error x Temp. Factor x 0.009 x V_S)
$V_S = 5.1 \pm 0.25$ Vdc

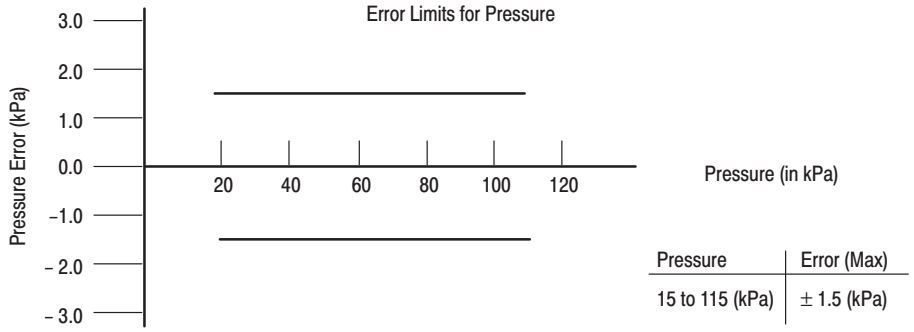
Temperature Error Band

MPX4115A, MPXA4115A Series



NOTE: The Temperature Multiplier is a linear response from 0°C to –40°C and from 85°C to 125°C

Pressure Error Band



Pressure	Error (Max)
15 to 115 (kPa)	$\pm$ 1.5 (kPa)

ORDERING INFORMATION — UNIBODY PACKAGE

Device Type	Options	Case No.	MPX Series Order No.	Marking
Basic Element	Absolute, Element Only	867	MPX4115A	MPX4115A
Ported Elements	Absolute, Ported	867B	MPX4115AP	MPX4115AP
	Absolute, Stove Pipe Port	867E	MPX4115AS	MPX4115A

ORDERING INFORMATION — SMALL OUTLINE PACKAGE

Device Type	Options	Case No.	MPX Series Order No.	Packing Options	Marking
Basic Element	Absolute, Element Only	482	MPXA4115A6U	Rails	MPXA4115A
	Absolute, Element Only	482	MPXA4115A6T1	Tape and Reel	MPXA4115A
Ported Element	Absolute, Axial Port	482A	MPXA4115AC6U	Rails	MPXA4115A
	Absolute, Axial Port	482A	MPXA4115AC6T1	Tape and Reel	MPXA4115A

Freescale Semiconductor, Inc.

ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

INFORMATION FOR USING THE SMALL OUTLINE PACKAGE (CASE 482)

MINIMUM RECOMMENDED FOOTPRINT FOR SURFACE MOUNTED APPLICATIONS

Surface mount board layout is a critical portion of the total design. The footprint for the surface mount packages must be the correct size to ensure proper solder connection interface between the board and the package. With the correct fottprint, the packages will self–align when subjected to a solder reflow process. It is always recommended to design boards with a solder mask layer to avoid bridging and shorting between solder pads.

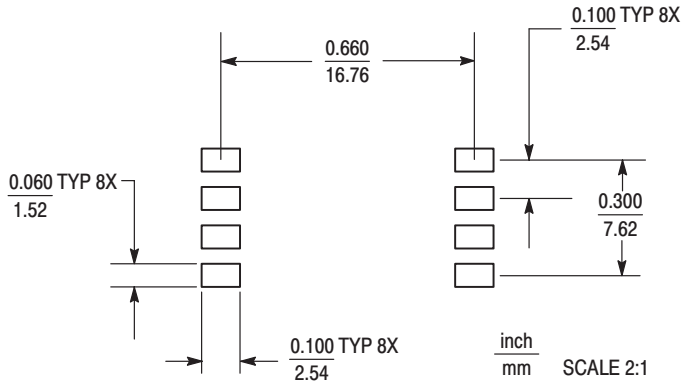
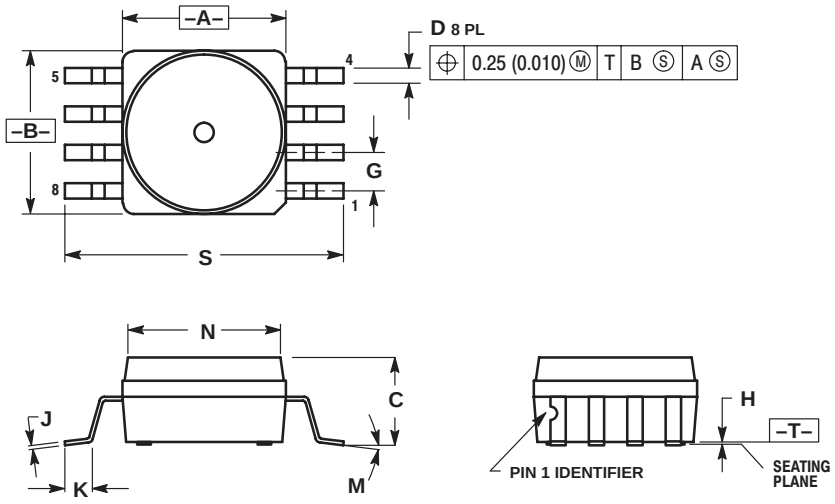


Figure 5. SOP Footprint (Case 482)

Freescale Semiconductor, Inc.

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

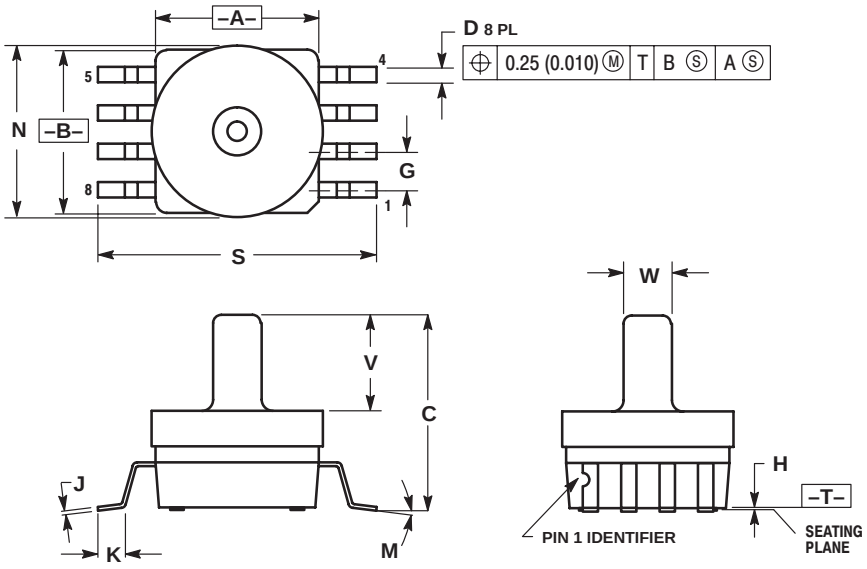
SMALL OUTLINE PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006).
5. ALL VERTICAL SURFACES 5° TYPICAL DRAFT.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.415	0.425	10.54	10.79
B	0.415	0.425	10.54	10.79
C	0.212	0.230	5.38	5.84
D	0.038	0.042	0.96	1.07
G	0.100 BSC		2.54 BSC	
H	0.002	0.010	0.05	0.25
J	0.009	0.011	0.23	0.28
K	0.061	0.071	1.55	1.80
M	0 °	7 °	0 °	7 °
N	0.405	0.415	10.29	10.54
S	0.709	0.725	18.01	18.41

CASE 482–01
ISSUE O



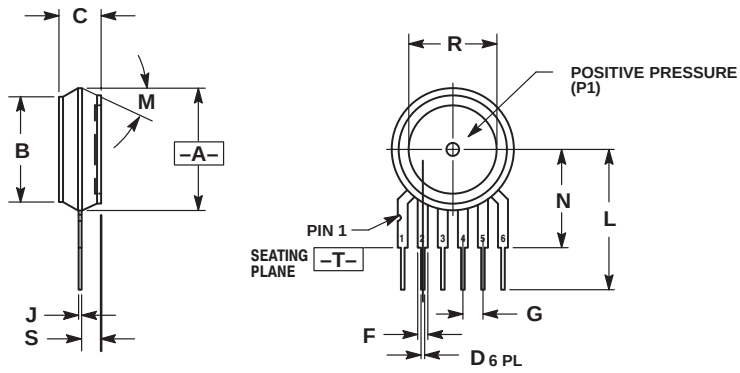
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006).
5. ALL VERTICAL SURFACES 5° TYPICAL DRAFT.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.415	0.425	10.54	10.79
B	0.415	0.425	10.54	10.79
C	0.500	0.520	12.70	13.21
D	0.038	0.042	0.96	1.07
G	0.100 BSC		2.54 BSC	
H	0.002	0.010	0.05	0.25
J	0.009	0.011	0.23	0.28
K	0.061	0.071	1.55	1.80
M	0 °	7 °	0 °	7 °
N	0.444	0.448	11.28	11.38
S	0.709	0.725	18.01	18.41
V	0.245	0.255	6.22	6.48
W	0.115	0.125	2.92	3.17

CASE 482A–01
ISSUE A

Freescale Semiconductor, Inc.

UNIBODY PACKAGE DIMENSIONS



NOTES:
9. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
10. CONTROLLING DIMENSION: INCH.
11. DIMENSION –A– IS INCLUSIVE OF THE MOLD STOP RING. MOLD STOP RING NOT TO EXCEED 16.00 (0.630).

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.595	0.630	15.11	16.00
B	0.514	0.534	13.06	13.56
C	0.200	0.220	5.08	5.59
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.40
L	0.695	0.725	17.65	18.42
M	30 ° NOM		30 ° NOM	
N	0.475	0.495	12.07	12.57
R	0.430	0.450	10.92	11.43
S	0.090	0.105	2.29	2.66

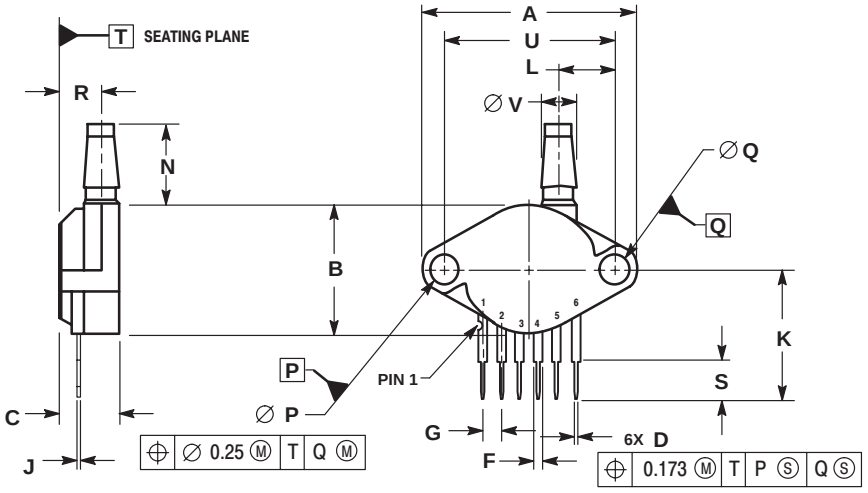
STYLE 1:
PIN 1. VOUT
2. GROUND
3. VCC
4. V1
5. V2
6. VEX

STYLE 2:
PIN 1. OPEN
2. GROUND
3. –VOUT
4. VSUPPLY
5. +VOUT
6. OPEN

STYLE 3:
PIN 1. OPEN
2. GROUND
3. +VOUT
4. +VSUPPLY
5. –VOUT
6. OPEN

CASE 867–08
ISSUE N

BASIC ELEMENT



NOTES:
1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.

	MILLIMETERS	
DIM	MIN	MAX
A	29.08	29.85
B	17.4	18.16
C	7.75	8.26
D	0.68	0.84
F	1.22	1.63
G	2.54 BSC	
J	0.36	0.41
K	17.65	18.42
L	7.37	7.62
N	10.67	11.18
P	3.89	4.04
Q	3.89	4.04
R	5.84	6.35
S	5.59	6.1
U	23.11 BSC	
V	4.62	4.93

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

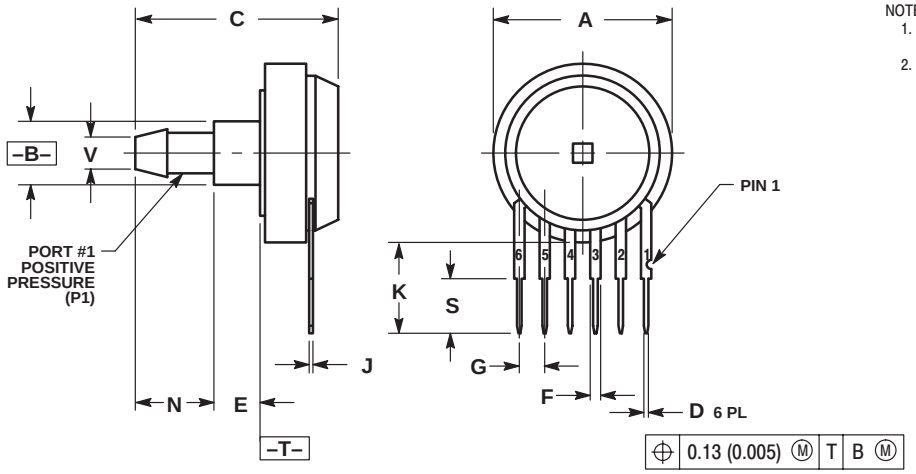
CASE 867B–04
ISSUE F

PRESSURE SIDE PORTED (AP, GP)

Freescale Semiconductor, Inc.

Freescale Semiconductor, Inc.
ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

UNIBODY PACKAGE DIMENSIONS—CONTINUED



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.690	0.720	17.53	18.28
B	0.245	0.255	6.22	6.48
C	0.780	0.820	19.81	20.82
D	0.027	0.033	0.69	0.84
E	0.178	0.186	4.52	4.72
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.345	0.375	8.76	9.53
N	0.300	0.310	7.62	7.87
S	0.220	0.240	5.59	6.10
V	0.182	0.194	4.62	4.93

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

CASE 867E–03
ISSUE D

PRESSURE SIDE PORTED (AS, GS)

Freescale Semiconductor, Inc.

ARCHIVED BY FREESCALE SEMICONDUCTOR, INC. 2005

Freescale Semiconductor, Inc.

Motorola reserves the right to make changes without further notice to any products herein. Motorola makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Motorola assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. “Typical” parameters which may be provided in Motorola data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including “Typicals” must be validated for each customer application by customer’s technical experts. Motorola does not convey any license under its patent rights nor the rights of others. Motorola products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Motorola product could create a situation where personal injury or death may occur. Should Buyer purchase or use Motorola products for any such unintended or unauthorized application, Buyer shall indemnify and hold Motorola and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Motorola was negligent regarding the design or manufacture of the part. Motorola and Ⓜ are registered trademarks of Motorola, Inc. Motorola, Inc. is an Equal Opportunity/Affirmative Action Employer.

How to reach us:
USA/EUROPE/Locations Not Listed: Motorola Literature Distribution;
P.O. Box 5405, Denver, Colorado 80217. 1–303–675–2140 or 1–800–441–2447

Technical Information Center: 1–800–521–6274

JAPAN: Motorola Japan Ltd.; SPS, Technical Information Center, 3–20–1, Minami–Azabu. Minato–ku, Tokyo 106–8573 Japan. 81–3–3440–3569

ASIA/PACIFIC: Motorola Semiconductors H.K. Ltd.; Silicon Harbour Centre, 2, Dai King Street, Tai Po Industrial Estate, Tai Po, N.T., Hong Kong. 852–26668334

HOME PAGE: http://www.motorola.com/semiconductors/

A.6 Ambient Temperature and Humidity Monitor

Omega Thermo-Hydrometer RH411

THERMO-HYGROMETER
VERY HIGH PERFORMANCE

3 YEAR WARRANTY | YEAR 2000 COMPLIANT

- **3-Year Warranty**
- **Unique Dual Display for Simultaneous Indication of BOTH Temperature and Relative Humidity**
- **Dual Simultaneous Analog Outputs for Temperature and Relative Humidity**
- **°C/°F Switchable**
- **Display Hold**
- **Min/Max Storage**
- **Sleep Mode to Prolong Battery Life**
- **Digital % RH and Temperature Calibration for Accuracy and Repeatability**

Model RH411
$349
Basic Unit

Shown slightly larger than actual size

U.S. Patented D316,053; 4,949,274; 4,864,226/ Canada 1,288,818/ Germany DE3879889T2/ Italy 0318549/ Japan-Pending/ UK0318549

Specifications

HUMIDITY MEASUREMENT

Range: 2 to 98% RH

Accuracy: 3% @ 25°C, between 20 and 90% of range; 5% @ 25°C, below 20% or above 90%

Sensor: Resistive polymer

Response Time: 30 seconds for a 30 to 80% step change

Display Resolution: 1% RH

TEMPERATURE MEASUREMENT

Range: -17 to 48°C; 2 to 120°F

Accuracy: 0.5°C/1°F

Sensor: Solid state

Response Time: 3 m for 63% step change

Display Resolution: 1°C/1°F

DISPLAY FUNCTIONS

Indication: Continuous, for both temperature and humidity

Min/Max: Storage of high and low readings for both temperature and humidity; user reset to clear stored values at any time

ANALOG OUTPUTS

Types: 10 mV/°F and 10 mV/%RH, continuous output; connected to >47 kΩ impedance

Connections: Standard banana plug; common ground connector for both outputs

MECHANICAL

Dimensions: 180 x 81 x 60 mm (7.1" x 3.2" x 2.4")

Probe: 12.7 mm x 76.2 mm (0.5" x 3")

Weight: 400 g (14 oz)

Display: 11 mm (0.42") LCD readout; 3-digit temperature, 2-digit humidity indication; custom indicators for measurement units (%RH, °F, °C, min, max, reset, display hold and low battery)

Meter Ambient Conditions: 10 to 40°C (50 to 104°F); 0-90% RH, non-condensing

Power: 9 V battery included and 110 Vac adaptor included

Battery Life: 100 h, alkaline battery

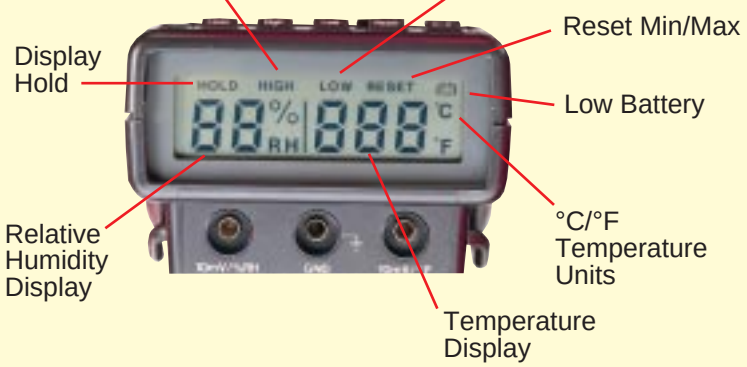
Sleep Mode: Unit shuts off after 15 minutes if no buttons are pushed.

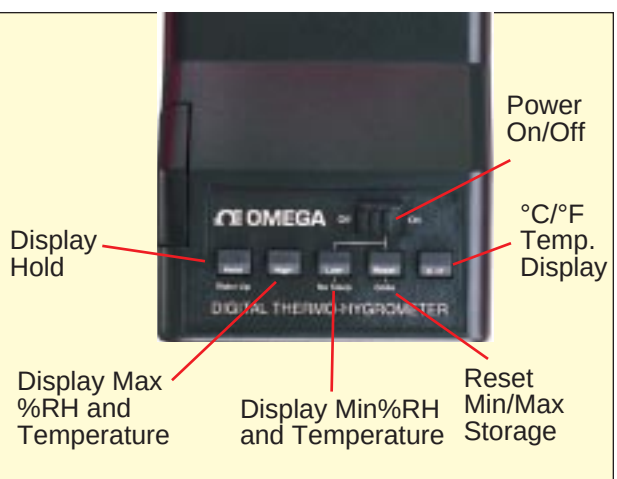
To Order *(Specify Model No.)*

Model No.	Price	Description
RH411	**$349**	Temperature /Rel Humidity Indicator*

**RH411 supplied with handheld temperature/ humidity sensor with 5' cable, 9 V battery, 110 V ac adaptor and operator's manual.*

Ordering Example:** RH411 digital temperature/humidity indicator **$349.





A.7 Hot Wire Anemometer

Extech Instruments Heavy Duty Hot Wire CFM Thermo-Anemometer

EXTECH INSTRUMENTS
A FLIR COMPANY

Experience the Extech Advantage®

PRODUCT DATASHEET

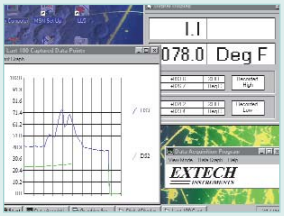
Heavy Duty Hot Wire CFM Thermo-Anemometer

Accurately measures Air Flow (CFM/CMM) or Air velocity plus ºF/ºC Temperature

Using the telescoping probe that extends up to 3ft 9940m) long

Features:

- Air velocity measurements as low as 40ft/min
- Telescoping probe is ideal for use in ducts and ventilating systems; extends up to 3ft (940mm) long
- Measures air volume in CFM (ft³/min) and CMM (m³/min) plus Temperature simultaneously
- Air Flow displayed in 2 modes as an instantaneous value or up to 20 point average
- Record/Recall MIN and MAX readings
- Super large 1.4" LCD display
- Data Hold plus Auto Power Off
- Built-in RS-232 PC interface with optional Data Acquisition software and cable
- Complete with telescoping probe with 5.5ft (167.6cm) cable, and four AA batteries



Optional Data Acquisition Software

Optional Battery Operated Datalogger

Specifications	Range	Resolution	Accuracy (%rdg+digits)
ft/min	40 to 3346ft/min	1ft/min	± (5% + 5 digits)
MPH	0.5 to 38.0MPH	0.1MPH	
knots	0.4 to 33.0knots	0.1 knots	
m/s	0.2 to 17.0m/s	0.1 m/s	
km/h	0.7 to 61.2km/h	0.1km/h	
Temperature	32 to 122°F	0.1°F	±1.5°F
	0 to 50°C	0.1 °C	±0.8°C
	Range	Resolution	Area
CMM (meter³/min)	0 to 36,000m³/min	0.001 to 1m³/min	0.001 to 30.0 m²
CFM (feet³/min)	0 to 1,271,200ft³/min	0.01 to 100ft³/min	0.001 to 322.91 ft²

Ordering Information:

407119 .....Heavy Duty Hot Wire CFM Thermo-Anemometer
407119-NIST.....407119 with NIST Certificate
407001 .....Data Acquisition program and cable
380340 .....Battery Operated Datalogger

CE 3 YEARS WARRANTY

Specifications subject to change without notice.
Copyright © 2008 Extech Instruments Corporation. All rights reserved including the right of reproduction in whole or in part in any form.

User's Guide

EXTECH INSTRUMENTS

Heavy Duty Hot Wire CFM Thermo-Anemometer

Model 407119A

Warranty

EXTECH INSTRUMENTS CORPORATION *warrants this instrument to be free of defects in parts and workmanship for* ***three years*** *from date of shipment (a six month limited warranty applies to sensors and cables). If it should become necessary to return the instrument for service during or beyond the warranty period, contact the Customer Service Department at (781) 890-7440 ext. 210 for authorization or visit our website www.extech.com for contact information. A Return Authorization (RA) number must be issued before any product is returned to Extech. The sender is responsible for shipping charges, freight, insurance and proper packaging to prevent damage in transit. This warranty does not apply to defects resulting from action of the user such as misuse, improper wiring, operation outside of specification, improper maintenance or repair, or unauthorized modification. Extech specifically disclaims any implied warranties or merchantability or fitness for a specific purpose and will not be liable for any direct, indirect, incidental or consequential damages. Extech's total liability is limited to repair or replacement of the product. The warranty set forth above is inclusive and no other warranty, whether written or oral, is expressed or implied.*

Introduction

Congratulations on your purchase of the Extech 407119A Thermo-Anemometer. The 407119A measures air velocity, air volume, and air temperature. It uses a telescoping probe antenna to allow convenient access to grills and diffusers. Careful use of this meter will provide years of reliable service. The Model 407119A features are listed below.

Features

- Combination hot wire probe (for air velocity) and thermistor sensor (for temperature) deliver rapid and precise measurements even at low air velocity values.
- Slim probe design with telescoping antenna for easy grill and diffuser access
- Air Velocity, Air Volume, and Air Temperature measurements
- 20 Reading Average feature
- Zero adjustment
- Data Hold and Record/Recall Max/Min features
- Auto Power OFF
- PC Interface (RS-232) with optional software and cable for data acquisition

Applications

Environmental testing, air conveyors, flow hoods, clean rooms, air balancing, fans/motors/blowers, furnace velocity, paint spray booths, and others.

Specifications

General Specifications

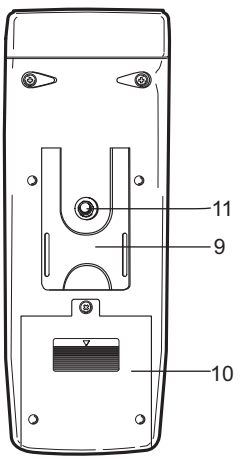
Display	Dual function 5-digit LCD
Measurement units	Air Velocity: m/s, km/h, ft/min, knots, mph; Air Flow: CMM (m^3/min) and CFM (ft^3/min);Temperature: °C and °F
Data hold	Freezes displayed reading
Sampling rate	Display update rate:1 second (approx.)
Sensors	Air velocity and temperature sensors: Thermistor type
MAX/MIN Memory	Record and view Maximum and Minimum readings
Average feature	Averages up to 20 readings
Automatic Power off	Auto shut off after 15 minutes
Data Output	RS-232 PC serial interface with 16-bit data stream output
Operating Temp.	32 to 122°F (0 to 50°C)
Operating Humidity	Max. 80% Relative Humidity
Power Supply	Four (4) 'AA' 1.5V batteries or optional AC adaptor
Power Current	70mA DC (approx.)
Weight (meter only)	1.15 lbs. (521g) with batteries installed
Dimensions	Main instrument: 7.9 x 3.0 x 1.5" (200.0 x 76.2 x 36.8mm) Telescoping Sensor: 0.5" (12.7mm) diameter head Min length of sensor: 8" (260mm); Max. length: 37" (0.94m) with 5.5' (1.7m) cable

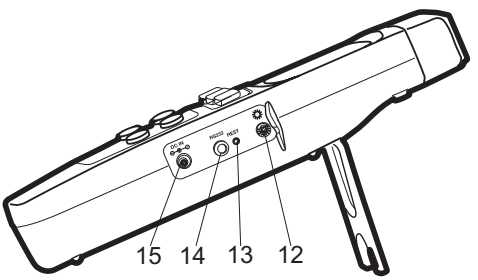
Range Specifications

Air Velocity	**Range**	**Resolution**	**Accuracy (of rdg)**
m/s (meters per second)	0.2 – 17.0 m/s	0.1	±(5% + 5 digits)
km/h (kilometers per hour)	0.7 – 61.2 km/h	0.1	±(5% + 20 digits)
ft/min (feet per minute)	40 – 3346 ft/min	1	±(5% + 100 digits)
mph (miles per hour)	0.5 – 38.0 mph	0.1	±(5% + 10 digits)
knots (nautical miles per hour)	0.4 to 33.0 knots	0.1	±(5% + 10 digits)
Air Flow Measurements	**Range**	**Resolution**	**Area Range**
CMM (cubic meters per min.)	0 – 36,000 m^3/min	0.001 to 1	0.001 to 30.0 m^2
CFM (cubic feet per minute)	0 – 1,271,200 ft^3/min	0.01 to 100	0.01 to 322.91ft^2
Air Temperature	**Range**	**Resolution**	**Accuracy**
	32 to 122°F (0 to 50°C)	0.1°F/C	±1.5°F (0.8°C)

Meter Description

1. Display
2. POWER button
3. HOLD and ESC button
4. REC and ENTER button
5. UNIT, ZERO, and ▲up arrow button
6. Function and ▼down arrow button
7. AVG. START, CLEAR, and ►right arrow button
8. AREA SET button
9. Tilt stand
10. Battery compartment / Cover
11. Tripod mount
12. LCD contrast adjustment pot
13. System reset switch
14. RS-232 Output terminal
15. DC9V power adaptor





Operation

Initialization and Zero procedures (please follow these steps before use)

Important Note: The meter's probe locking switch must be in the locked position (with the probe inserted) for the meter to turn on and operate correctly. Refer to the accompanying diagram or the diagram at the top of the meter for switch orientation.

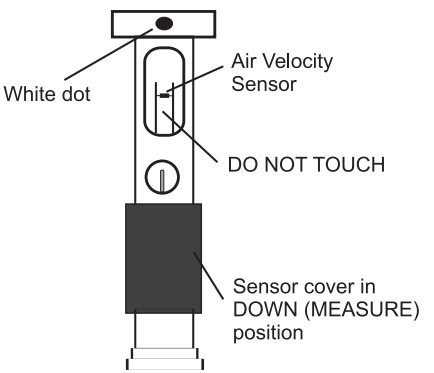
TOP VIEW OF METER

LOCKED Position

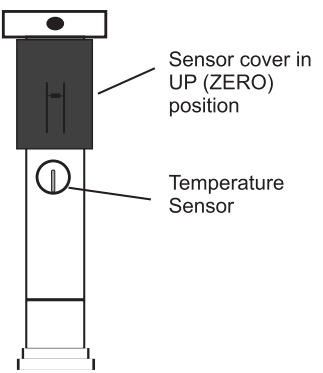
UNLOCKED Position

For the best accuracy and for proper operation, the following steps must be performed.

1. Connect the sensor to the input jack on top of the meter by first unlocking the sensor jack and then inserting the sensor plug. Lock the sensor jack after the probe is inserted.
2. Press the POWER button to turn on the meter. The meter will perform a self-test during which the display will count down from 9999 to 0000.
3. Select the air velocity function using the FUNCTION button. The LCD will display the most recently selected unit of measure for air velocity.
4. To change the temperature units of measure (C/F), use the advanced programming mode discussed later in this manual.
5. Momentary presses of the UNIT button changes the air velocity units. The LCD will reflect the selection.
6. Place the sensor cover in the up (ZERO) position (see diagram below).
7. Open the telescoping sensing antenna to a convenient length.
8. Place the sensor in the area to be measured and allow a short time for it to stabilize to the ambient temperature.
9. To Zero the meter display, press and hold the ZERO button until the second beep.



Measurement Position



Zero Position

Warning! Do not touch the air velocity or temperature thermistors inside the sensor head while moving the sensor cover.

Air Velocity Measurements

1. Follow the Initialization and Zeroing procedures above before continuing.
2. Open the antenna to the desired length.
3. Slide the air velocity sensor cover down.
4. Press the POWER button to turn the meter on.
5. Place the sensor in the air current to be measured. Have the air flow meet the sensor head in the direction of the white dot (as shown in diagram).

6. View the air velocity and temperature readings on the LCD Display. The large main LCD display shows the Air Velocity reading. The lower LCD sub-display shows the temperature reading (left) and the unit of measure (right).
7. To turn the meter off, press and hold the POWER button until the meter switches off.

Air Flow (Volume) Measurements (CMM / CFM)

NOTE: Temperature is not displayed while the meter is in the Air Flow mode.

1. Follow the steps in the Initialization and Zeroing section before continuing.
2. Select the air flow mode using the Function button. The LCD will display CMM (cubic meters per minute) or CFM (cubic feet per minute) when Air Flow is selected.
3. Press the UNIT button momentarily to select the desired air flow units: CMM or CFM. The LCD display will reflect the selection.
4. Calculate the area of the duct or vent under test (refer to the Useful Conversions and Equations section in the back of this manual for assistance). Be sure to compute the area of the vent or duct in square feet or meters. If you have the area in inches, convert inches to feet before programming the meter with the area value.
5. Press the AREA SET button to begin entering the area in m^2 or ft^2. The left digit will begin flashing. Follow the steps below to enter the area of the duct or vent in question:

   Use the ► button to select a digit to change (digit will flash)
   Use the ▲ button increase the value of the flashing digit
   Use the ▼ button to decrease the value of the flashing digit

6. Press the REC/Enter button and then the AREA SET button to save the new area value
7. After the area has been entered, the new area value will be shown on the lower left of the LCD display in ft^2 or m^2. If the unit of measure is CFM, the area will be shown in square feet. If the unit of measure is CMM, the area will be shown in meters squared.
8. Press the ESC button to abort the programming at any time.
9. Place the probe in the area under test. The main LCD digits will indicate the air flow in CFM or CMM. If the CFM or CMM reading exceeds 99999, use the displayed X10 multiplier to calculate the reading.
10. To turn the meter off, press and hold the POWER button until the meter switches off.

AVERAGE Feature for the Air Flow Mode

In the Average mode, up to 20 readings can be stored and averaged.

1. In the Air Flow Mode (discussed earlier), press the FUNCTION button momentarily until the AVG icon and a 'zero' appears on the lower LCD display line.
2. Press the AVG START button to record the current reading. A '1' will appear on the lower LCD line indicating that one reading has been stored.
3. Press the AVG START for up to a total of 20 measurements. The number on the lower LCD line will increment with each press of the AVG START button letting the user know how many readings are currently being averaged. Note that only the averaged reading is shown while in this mode, not the actual reading.
4. To clear (erase) all of the currently stored readings and start again, press and hold the AVG button until the meter beeps twice. Note that the counter resets to '0' and that the meter is ready to start another averaging session.
5. Use the FUNCTION button to exit this mode of operation.

Data Hold Feature

1. While taking measurements, press the HOLD button to freeze a reading.
2. The HOLD indicator will appear on the LCD when the display is in Data Hold mode.
3. Press HOLD again to return to normal operation.

Maximum (MAX) and Minimum (MIN) Recording

The MAX / MIN Record-Recall feature allows the user to record and view the highest and lowest readings during a measurement session.

1. Press the REC button once. The REC indicator will appear on the display and the meter will begin keeping track of the MAX and MIN values.
2. To view the MAX reading, press REC again. The MAX indicator along with the maximum reading will appear on the LCD display.
3. Press REC again to view the minimum value, the MIN indicator along with the minimum reading will appear on the LCD display.
4. To return to normal operation, press and hold the REC button for approx. 3 seconds (until the meter beeps). The display indicators REC, MAX, and MIN will disappear.

Note: Auto Power Off is disabled in the RECORD mode.

Auto Power Off

To save battery life, the meter will automatically shut off after approximately 15 minutes of operation. To temporarily disable this feature (until the meter's power is cycled), press the REC button and enter the RECORD mode. Alternatively, go to the advanced programming section (later in this manual) for instructions on how to disable it long term.

Advance Programming Mode

From the Air Velocity mode of operation, press and hold the SET button until the meter beeps and a '1' is displayed. The advanced programming mode is now accessed. The Auto Power OFF Enable/Disable and the Temperature Units selections are available in the advanced programming mode. Use the ESC button to exit this mode at any time.

Auto Power Enable/Disable

The first parameter in the advanced mode is the Auto Power OFF enable/disable. Use the up and down arrow keys to select the desired value. '0' defeats the Auto Power OFF feature; '1' enables the Auto Power OFF feature. Momentarily press the SET button to move to the next parameter temperature units (see below).

Temperature Units selection (C/F)

The second parameter in the advanced mode is the Temperature Units selection. Use the up and down arrow keys to select the desired value. '0' selects degrees 'C'; '1' selects degrees 'F'. Press the ESC button to exit the advanced programming mode.

System Reset

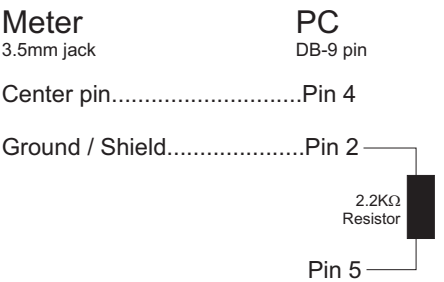
If the meter's display 'locks up' and/or the button presses do not cause the display to change, try a system reset. To reset the meter, use one of the following methods.

1. Move the probe lock switch from the ON to the OFF to the ON position again. Turn the meter on.
2. While powering the meter, press the RESET switch (side compartment) using the point of a paper clip.

PC Interface

The 407119A is equipped with a 3.5mm jack (side compartment) for connection to a PC for data acquisition purposes. The meter's data output is a 16 bit data stream. To obtain PC interface cabling and Windows™ data acquisition software, contact Extech Instruments. Instructions for use are provided with the software. The PC interface cable schematic, data stream protocol, and RS-232 communication settings are provided below.

PC Interface Cable schematic



Protocol for 16-bit data stream

D0	End Word = '0D'
D1 & D8	Displayed reading; D1 = LSD; D8 = MSD. For example, For a displayed reading of 1234, D8 through D1 is 00001234
D9	Decimal point (right to left): 0 = no decimal; 1 = 1 place; 2 = 2 places; 3 = 3 places
D10	Polarity: 0 = positive; 1 = negative
D11 & D12	Displayed unit of measure: 01 = °C; 02 = °F; 08 = m/s; 09 = knots; 10 = km/hr; 11 = ft/min; 12 = MPH; 84 = CMM; 85 = CFM; 0A = Square meter (area); 0B = Square feet (area)
D13	1 = Upper LCD display digits; 2 = Lower LCD display digits
D14	Always '4'
D15	Start word '02'

RS-232 Settings

Baud rate: 9600

Parity: No parity

Data bits: 8

Stop bits: 1

Battery Replacement

When the battery icon appears on the lower left corner of the LCD display, the four (4) 'AA' batteries must be replaced.

1. Remove the rear Phillips head screw
2. Slide off the rear battery compartment
3. Replace the batteries
4. Secure the battery compartment

Calibration and Repair Services

Extech offers repair and calibration services for the products we sell. Extech also provides NIST certification for most products. Call the Customer Service Department for information on calibration services available for this product. Extech recommends that annual calibrations be performed to verify meter performance and accuracy.

☎

Support line (781) 890-7440

Technical support: Extension 200; E-mail: support@extech.com

Repair & Returns: Extension 210; E-mail: repair@extech.com

Product specifications subject to change without notice

For the latest version of this User's Guide, Software updates, and other up-to-the-minute product information, visit our website: www.extech.com

Extech Instruments Corporation, 285 Bear Hill Rd., Waltham, MA 02451

Copyright © 2005 Extech Instruments Corporation

All rights reserved including the right of reproduction in whole or in part in any form.

Useful Equations and Conversions

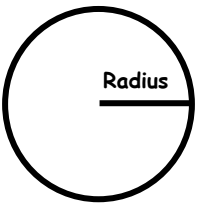
Area equation for rectangular or square ducts

Height (H)

Width (W)

Area (A) = Width (W) x Height (H)

Area equation for circular ducts



Area (A) = $\pi \times r^2$

Where π = 3.14 and r^2 = radius x radius

Cubic equations

CFM (ft^3/min) = Air Velocity (ft/min) x Area (ft^2)

CMM (m^3/min) = Air Velocity (m/sec) x Area (m^2) x 60

NOTE: Measurements made in *inches*
must be converted to *feet* or *meters* before using the above formulae.

Unit of Measure Conversion Table

	m/s	ft/min	knots	km/h	MPH
1 m/s	1	196.87	1.944	3.6	2.24
1 ft/min	0.00508	1	0.00987	0.01829	0.01138
1 knot	0.5144	101.27	1	1.8519	1.1523
1 km/h	0.2778	54.69	0.54	1	0.6222
1 MPH	0.4464	87.89	0.8679	1.6071	1

A.8 Digital Manometer

LOVE Series HM28 Handheld Digital Manometer

Series HM28

Handheld Digital Manometer

High Accuracy (0.2%, 0.1% or 0.05%), Differential, Gage or Absolute

CE

STANDARD FEATURES

- **Microprocessor based**
- **Differential, Gage, or Absolute**
- **High Accuracy, 0.2%, 0.1%, or 0.05% with Calibration Certificate**
- **Selectable Scales**
- **Resolution to 0.000 of Selected Unit**
- **Peak and Valley Indication**
- **Hold Function**
- **Programmable Display**
- **Memory for up to 964 Readings**
- **Output for Optional Printer or Computer Interface**

The Series HM28 Digital Hand-Held Manometer is a precision instrument designed to measure a wide range of pressures to a very high accuracy. The unit incorporates a variety of features in an easy to use format that makes it useful in a wide variety of applications. Features include: measurement in all common pressure ranges, display resolution to 0.001, differential or relative measurement, two line liquid crystal display, and adjustable auto power off to conserve battery.

We are so proud of the accuracy of the HM28 that we provide a certificate of calibration with the unit at no additional cost. Depending on your application, the HM28 can be used as a secondary calibration standard for your other pressure instrumentation.

INPUT RANGES

RANGE (US)	RANGE (METRIC)	OVERPRESSURE
Gauge, underpressure and differential pressure		
0-10 in H_2O	0-2.5 kPa	12.5 kPa (50 in H_2O)
0-28 in H_2O	0-7 kPa	35.0 kPa (140 in H_2O)
0-80 in H_2O	0-20 kPa	150 kPa (600 in H_2O)
0-120 in H_2O	0-30 kPa	150 kPa (600 in H_2O)
0-200 in H_2O	0-50 kPa	400 kPa (1600 in H_2O)
0-14.5 psi	0-100 kPa	400 kPa (58 psi)
0-29 psi	0-200 kPa	700 kPa (100 psi)
0-100 psi	0-700 kPa	1700 kPa (246 psi)
0-145 psi	0-1000 kPa	2700 kPa (390 psi)
0-245 psi	0-1700 kPa	2700 kPa (390 psi)
for Gauge, media compatible with 18/8 SS (DIN 1.4305)		
0-14.5 psi	0-100 kPa	200 kPa (29 psi)
0-29 psi	0-200 kPa	400 kPa (58 psi)
0-100 psi	0-700 kPa	1400 kPa (203 psi)
0-145 psi	0-1000 kPa	3400 kPa (493 psi)
0-245 psi	0-1700 kPa	3400 kPa (493 psi)
0-435 psi	0-3000 kPa	7000 kPa (1015 psi)
0-1000 psi	0-7000 kPa	14000 kPa (2030 psi)

Accessories

HM28-0 1/8″ NPT Adaptor 2 pieces . . . . . .
HM28-1 Communication Software & Cable . . . . . .
HM28-2 Universal Power Adaptor . . . . . .

SPECIFICATIONS

Pressure Connection: Hose; 4/6 mm or 1/8″ NPT.
Accuracy (includes linearity, hysteresis, and repeatability): per order code. ±0.20% full scale ±1 digit
±0.10% full scale ±1 digit
±0.05% full scale ±1 digit
Measuring Media: Instrument Air or Inert Gases. For HM28G3XXXXX, Any material compatible with 18/8 stainless steel.
Temperature Limits: 23 to 122°F (-5 to 50°C).
Storage Temperature: -4 to 140°F (-20 to 60°C).
Humidity: 30 to 95% rH, non-condensing.
Display: 2 line, 16 character, dot matrix LCD, with switchable display sizes.
Battery: 9V alkaline (included). Can operate from external power supply of 7 to 14 VDC.
Current Consumption: <9 mA.
Memory: 964 measured values. Recording intervals adjustable from manual, 1, 5, 10, 20, 30 seconds, 1, 2, 3, 5, 10, 30, 60 minutes.
Case Protection: IP54.
Case Dimensions: 6 x 3.27 x 1.34 in (152 x 83 x 34 mm).
Weight: 9.5 oz (270 g).
Maximum Measurement Rates: Stand alone: 2-1/2 readings/sec (0.1% and 0.05% ratings), 5 readings/sec (0.2% rating). Output to RS-232: 20 measurements/sec (0.2% rating). 10 measurements/sec (0.1% and 0.05% ratings).
RS-232 Baud Rate: Adjustable, 1200, 2400, 4800, or 9600 baud.
Agency Approvals: CE.

MODELS

Part Number	Features
Error limit 0.2% F.S. for gage, underpressure and differential pressure	
HM28D3B10000	0-10 in H_2O (2.5 kPa)
HM28D3C10000	0-28 in H_2O (7 kPa)
HM28D3F10000	0-120 in H_2O (30 kPa)
HM28D3H10000	0-14.5 psi (100 kPa)
Error limit 0.05% F.S. for gage, underpressure and differential pressure	
HM28D3C30000	0-28 in H_2O (7 kPa)
HM28D3F30000	0-120 in H_2O (30 kPa)
HM28D3H30000	0-14.5 psi (100 kPa)
HM28D3K30000	0-100 psi (700 kPa)
HM28D3M30000	0-245 psi (1700 kPa)
For Absolute pressure	
HM28A3I10000	0-15.9 pisa (0.2% F.S. (110 kPa abs)

MOD-TRONIC INSTRUMENTS LIMITED
1 Delta Park Blvd, #12 Brampton, ON L6T 5G1
Tel 905-457-6322 or 1-800-794-5883
Fax 905-457-4716 or 1-800-830-7122
sales@mod-tronic.com www.mod-tronic.com

A.9 Fuel Flow Meter

FloCat C-SF45-A001 Hydrocarbon Flow Meter

FLOCAT

Flow meters, applications assistance and technical support

C-SF45-A Series
Instruction Manual

C-SF99-B001

FLOCAT
2200 South Street
Racine WI, 53404
www.flocat.com

Phone: 888-356-9888 Fax: 800-775-3179 e-mail: sales@flocat.com

DESCRIPTION:

C-SF45-A series turbine flow sensors measures the flow of hydrocarbon fuels such as gasoline, kerosene, #2 diesel fuel, and other light transmitting, non-corrosive liquids of similar viscosity. Typical fuel flow applications include aircraft fuel monitoring systems; gasoline, diesel, and gas turbine engine test stands; and industrial furnaces.

The transducers give repeatable signals on gasoline across a 100 to 1 flow range down to 0.3 GPH. The higher viscosity of diesel fuel reduces signal repeatability at flow rates below 2 GPH. Pressure drops are very low compared to other turbine flow sensors. The sensor's bearing system is rated for continuous operation at the upper end of the flow range.

The sensor produces a current pulse signal from an opto-electronic pickup with a preamplifier.

PRINCIPAL OF OPERATION

Liquid enters the flow chamber tangentially, follows a helical flow path, and exits vertically, thereby venting any entrained vapor bubbles. The rotational velocity of the liquid is directly proportional to flow rate. A neutrally buoyant rotor spins with the liquid between V-jewel bearings. Rotor movement is sensed when notches in the rotor interrupt an infrared light beam between an LED and phototransistor.

The vapor venting design requires that the transducer be positioned with the wires pointing up. Turbulence caused by valves or sharp elbows mounted close to the transducer inlet can affect the sensor's K-Factor and should be minimized.

PERFORMANCE SPECIFICATIONS

Model Number	C-SF45-A001	C-SF45-A002	C-SF45-A003
Flow Range,			
Gasoline	0.3 - 30 GPH	0.6 - 60 GPH	2.0 - 80 GPH
#2 Diesel	2.0 - 30 GPH	3.0 - 60 GPH	8.0 - 80 GPH
Approximate K Factor (Pulses/Gallon @ 16 GPH)			
Gasoline	32,000	28,000 - 31,000	24,000
#2 Diesel	33,000	28,000	25,000
Pressure Drop			
Gasoline	0.6 psi @ 15 GPH	1.2 psi @ 30 GPH	1.4 psi @ 40 GPH
	2.4 psi @ 30 GPH	4.8 psi @ 60 GPH	5.8 psi @ 80 GPH
#2 Diesel	0.8 psi @ 15 GPH	1.5 psi @ 30 GPH	1.8 psi @ 40 GPH
	3.0 psi @ 30 GPH	6.0 psi @ 60 GPH	7.2 psi @ 80 GPH
Repeatability	±¼% @ 16 GPH	±¼% @ 16 GPH	±¼% @ 16 GPH
Working Pressure	200 psi	200 psi	200 psi
Temperature Range	-65° / 100°C	-65° / 100°C	-65° / 100°C
Bearing Life Expectancy	10,000 hr. min.	10,000 hr. min.	10,000 hr. min.

C-SF45-A SERIES FLOW SENSOR INSTALLATION

Sensors must be placed in a horizontal section of fuel line at a low point in the fuel system. Fuel should travel, “Up-hill” when exiting the sensor. Its outlet should be at least 1 or 2 inches lower than the fuel pump inlet, or priming bulb. Placing the sensor at least 12” upstream of the fuel pump improves system accuracy.

To prevent the sensor from clogging, it is recommended that the sensor(s) be installed down-stream of a coarse fuel filter or water separator. For applications not equipped with an off engine filter we suggest installing a model ILA-02 Flow Ezy filter w/238 micron screen directly to the inlet of the flow sensor.

Caution: Never Plumb Flow Sensor(s) Downstream of an Engine Mounted Fuel Filter.

The sensors ports are marked with IN and OUT. They must be installed with the proper orienta-tion and with the wires up.

Minimize the number of 90º elbows and pipe fittings. Excessive use may create a high vacu-um, fuel restricting pressure drop across the fuel system. Whenever possible, use a large ra-dius hose bend instead of elbows. Refer to the engine owner’s manual for maximum fuel pump vacuum. A vacuum gauge can be used to confirm that the system is within limits.

DO NOT OVER TIGHTEN FITTINGS. Torque pipe thread fittings to a maximum of 15 ft-LB, (180 inch-Lb) or two full turns beyond hand tight, (Whichever comes first). FloCat recommends that a fuel proof pipe thread sealant be used when installing fittings into the flow sensors, (LockTite PST, Rector Seal, Leaklok, Permatex, Jomar, etc). NEVER USE TEFLON TAPE.

If swivel fittings are used, (JIC or SAE) their mating surfaces should be sealed with AP 50 Fit-ting Seals, or Copper Conical Sealing Washer, (Connie Seals)

MATERIAL SPECIFICATIONS:

Flow Sensor Body	Die-cast Aluminum, Cadmium Plated, Dichromate Finish
Rotor	Nylon 6/12
Rotor Pivot	Stainless Steel, Carpenter 420
Phototransistor	SD 1440
Light Emitting Diode	SE 1450
Connectors	22 Gauge Wire Leads (3)

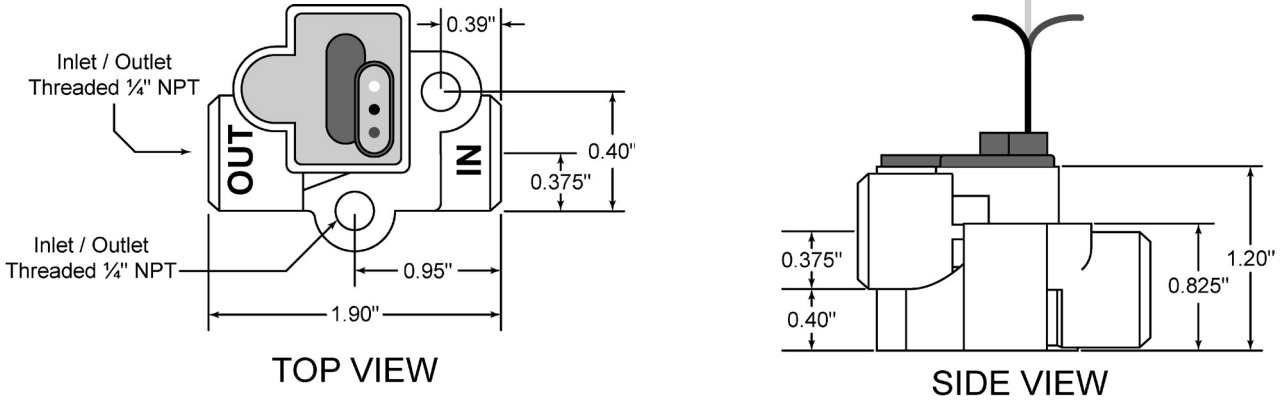
ELECTRICAL SPECIFICATIONS:

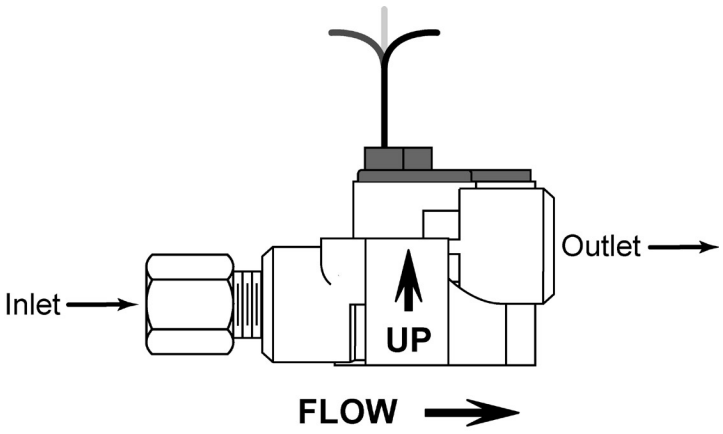
12 to 15 VDC between RED (+) wire and BLACK (-) wire. 30 to 50 mA at 12 VDC.

SIGNAL SPECIFICATIONS:

Open collector transistor output on WHITE wire. Sensor will pull-down to 1.0 volt with 10 - 15k ohm pull-up resistor installed.

DIMENSIONS





TEST THE FLOW SENSORS.

At the readout, disconnect the RED (switched +12 VDC) wire from the switched source and temporarily connect it to an un-switched source so the instrument is powered even when the engine is OFF. All other wires are as per the wiring diagram.

FINDING SUCTION LEAKS IN FUEL SYSTEMS

By far, the most common complaint received is FLUCTUATING GPH READINGS or HIGH READINGS caused by a suction leak somewhere between the fuel tank and the inlet of the fuel pump. The symptom of a suction leak shows up on the GPH reading as a fluctuation. The more severe the leak, the greater the fluctuation will be. Typically, the fluctuation is around 2 - 4 GPH. This also affects the totalizer reading and usually shows a 15 - 30% higher reading than what you've put into the tank. Suction leaks occur with both gasoline and diesel engines and will not affect engine performance except in severe cases.

If you have fluctuating readings, but the totalizer reading is close to what you've put into the tank (+/- 6%), something is causing the fuel to flow through the system that way. The most likely causes are an anti-siphon valve set too stiff or a sticky or misadjusted float valve on the gasoline engine's carburetor. Repair or replace as needed.

Finding suction leaks can be a tedious and time-consuming chore, but properly approached, it can be repaired in a minimum amount of time. The two most common places for suction leaks to occur are at the primary fuel filter/water separator and/or from a loose valve stem packing gland nut.

First, remove the filter housing. Coat any o-rings or gaskets you find with a coating of light grease (not machine oil or diesel oil) and reassemble. Gently tighten all valve stem packing gland nuts. Do not over tighten, valve should turn freely. Tighten all hose clamps and compression fittings (do not over tighten). Run the engine for 5 - 10 minutes and observe readings. If you've found the problem, the fluctuations should reduce to less than ½ GPH of the reading.

If this does not cure the problem, the next step is to temporarily insert a clear piece of fuel resistant tubing. For gasoline engines, install it to the inlet of the fuel pump. For diesel engines, install it after the return flow sensor. Run the engine and watch the clear tubing for signs of a constant stream of small bubbles or an occasional larger bubble. Sometimes shining a light through the clear tube makes it easier to see.

Have someone observe the clear tube while you move any flexible hose(s) in the fuel system. If the amount of bubbles observed continually increase or decreases as you do this, you have found the area causing the leak. Repair or replace as needed. If it is a one time occurrence, you probably dislodged some air trapped in the fuel line.

If you haven't found it yet, the last step is to inspect each pipe joint in the system. You should be able to see joint compound all the way around the joint. If you do not, that joint is suspect and needs to be resealed. You should now see the clear tube running with solid fuel and free of any bubbles. You may need to run the engine for a few minutes to purge any air that was in the system. If you still see bubbles in the clear tubing, you missed the leak somewhere and need to check back over your work. Remove the clear tube and restore the fuel system to its normal condition.

FUEL FILTERS

A dirty fuel filter or one that is too fine (1-5 micron) may cause cavitation (drawing vapor out of the fuel). Replace the filter with a new one in the 10-20 micron range or larger, depending on engine manufacturers recommendations.

FLOW SENSOR ORIENTATION

The importance of proper orientation of the flow sensor can not be emphasized enough. All flow sensors come with the inlet and outlet distinctly marked (IN / OUT). This signifies fuel flow direction and is imperative for the sensor to work correctly in the system. There is an additional arrow on the body of the flow sensor. This will either be a label clearly marked or stamped onto

the body of the sensor itself. It is crucial that this single arrow points up. Please be careful to install the sensor in the proper orientation. Before installing the sensor(s), familiarize yourself how the sensor(s) is to be installed.

LOW RPM OPERATION

At idle, under no load conditions, it is not uncommon for the GPH reading to fluctuate by as much as .2 -.3 GPH. This fluctuation is caused by the engine governor fluctuating the fuel flow to maintain engine RPM.

A.10 DAQ System

National Instruments CompactDAQ

NI CompactDAQ Overview

Simple Complete USB Data Acquisition

NI CompactDAQ provides the plug-and-play simplicity of USB to sensor and electrical measurements on the benchtop, in the field, and on the production line. By combining the ease of use and low cost of a data logger with the performance and flexibility of modular instrumentation, NI CompactDAQ provides fast, accurate measurements in a small, simple, and affordable system.

With the flexible NI software options, you can easily use NI CompactDAQ to log data for simple experiments or to develop a fully automated test or control system. The modular design can measure up to 256 channels of electrical, physical, mechanical, or acoustical signals in a single system. In addition, per-module analog-to-digital converters and individually isolated modules ensure fast, accurate and safe measurements.

Figure 1. NI CompactDAQ packs USB DAQ, signal conditioning, and sensor connectivity for up to 256 channels in a 25 by 9 by 9 cm system.

Go to the CompactDAQ homepage: www.ni.com/compactdaq

More Performance, Lower Price

NI CompactDAQ takes advantage of technology from National Instruments industry-standard M Series data acquisition devices and highest performance CompactRIO control systems to optimize both performance and price. NI CompactDAQ uses the same C Series I/O modules as other NI measurement and control platforms, so production costs are minimized through high volume economies of scale. The modules use commercially available components and circuitry from vendors such as Analog Devices and Texas Instruments, which provide measurement resolution as high as 24 bits (more resolution than a 6 1/2 digit DMM) at prices much lower than custom-designed components used in other data acquisition systems.

LabVIEW™, National Instruments™, and ni.com™ are trademarks of National Instruments Corporation. Product and company names mentioned herein are trademarks or trade names of their respective companies. For patents covering National Instruments products, refer to the appropriate location: Help»patents in your software, the patents.txt file on your CD, or ni.com/patents.

© Copyright 2006 National Instruments Corporation. All rights reserved.

Flexibility with over 40 Measurement Modules

Because many data acquisition systems have fixed functionality, they can connect only to specific sensor types. Other systems are modular, but are capable of measuring only low speed and static signal such as DC voltage and temperature. NI CompactDAQ can measure dynamic signals such as sound, vibration, pressure, and electrical transients at up to 50 kS/s per channel in addition to static signals such as DC voltage and temperature. Other modules provide single-point and waveform output capability at rates up to 100 kS/s/channel, or digital I/O at rates up to 10 MHz. Because NI CompactDAQ is a modular system, additional measurement types and channels can be added to the system by simply plugging in additional modules. All modules are automatically synchronized, and a single NI CompactDAQ system can simultaneously stream high-speed analog input, analog output, digital input, and digital output over a single USB connection.

For a complete list of available modules, please refer to the C. Series I/O Modules family page.

	Model	Ch	Range	Res.	Description	Rate
Analog Input	NI 9201	8	±10 V	12-bit	Low cost	500 kS/s
	NI 9203	8	±20 mA	16-bit	Current	200 kS/s
	NI 9205	32	±10 V	16-bit	Multiplexed	250 kS/s
	NI 9206	16	±10 V	16-bit	500 V (isolation)	250 kS/s
	NI 9211	4	±80 mV	24-bit	Thermocouple	14 S/s
	NI 9215	4	±10 V	16-bit	Simultaneous	100kS/s/ch
	NI 9217	4	100 #	24-bit	RTD	400 S/s
	NI 9219	4	Various	24-bit	11 Modes	100S/s/ch
	NI 9221	8	±60 V	12-bit	High voltage	800 kS/s
	NI 9229	4	±60 V	24-bit	Ch-to-ch isolation	50 kS/s/ch
	NI 9233	4	±5 V	24-bit	IEPE sensors	50 kS/s/ch
	NI 9237	4	±25 mV/V	24-bit	Strain/bridge	50 kS/s/ch
	NI 9239	4	±10 V	24-bit	Ch-to-ch isolation	50 kS/s/ch
AO	NI 9263	4	±10 V	16-bit	Voltage AO	100kS/s/ch
	NI 9265	4	0-20 mA	16-bit	Current AO	100kS/s/ch

Digital	NI 9401	8	5 V TTL	#	DIO	10 MHz
	NI 9411	6	5 to 24 V	#	DI	2 MHz
	NI 9421	8	24 V	#	DI (sink)	10 kHz
	NI 9422	8	24 to 60 V	#	DI (sink/source)	4 kHz
	NI 9423	8	24 to 30 V	#	DI (sink)	1 MHz
	NI 9225	32	12 to 24 V	#	DI (sink)	140 kHz
	NI 9235	4	5 to 250 V	#	Universal	333 Hz
	NI 9472	8	24 V	#	DO (source)	10 kHz
	NI 9474	8	5 to 30 V	#	DO (source)	1 MHz
	NI 9476	32	6 to 36 V	#	DO (source)	2 kHz
	NI 9477	32	5 to 60 V	#	DO (sink)	125 kHz
Relay	NI 9481	4	250 VAC	#	Solid-state relay	50 Hz
	NI 9485	8	±60 V	#	Solid-state relay	50 Hz

For a complete list of available modules, please refer to the C. Series I/O Modules family page.

NI CompactDAQ Advantages

Future-Ready Flexibility

NI CompactDAQ is much more flexible than traditional instruments at adapting to changes in test requirements. Traditional instruments pack processors, memory, software and displays into a fixed-functionality box that can quickly become obsolete. Instead, NI CompactDAQ uses the speed, power, and data storage capability of your PC. If you need more data storage or faster data processing, you can upgrade your PC memory instead of buying a new higher-end instrument. And adding a new type of measurement or expanding channel count is as easy as plugging in an additional module into the NI CompactDAQ chassis.

Unlike other data acquisition systems, NI CompactDAQ does not use electromechanical relays to switch analog input signals. Relays wear out over time, potentially causing failure of the system and test. Relays are also limited to switch rates of about 1000 S/s. Instead, NI CompactDAQ uses solid-state multiplexers that do not wear out over time and can switch input channels at rates up to 250 thousand times per second for accurate and reliable high-speed measurements.

Connectors, Signal Conditioning, and DAQ in a Single Package

Assembling a data acquisition system often involves cabling signal conditioning and connector blocks to a separate device to digitize input signals. These cables and connector blocks add cost and can contribute to noise and error in the system. NI CompactDAQ combines signal connectors, signal conditioning, and analog-to-digital converters in a single package. This feature eliminates the time and guesswork associated with cabling together multiple components and

reduces the number of components that can contribute to noise or failure.

NI CompactDAQ modules include connectors matched to the measurement capability of the module. For example, general-purpose voltage input modules have removable screw terminals, while modules for dynamic and transient signals have BNC connectors. By matching the connectors with the measurement capability of the modules, NI CompactDAQ simplifies sensor and signal installation and further reduces the potential for error by eliminating wire cutting, stripping, and crimping.

Figure 2. C Series modules for NI CompactDAQ include sensor-specific connectors with built-in signal conditioning and A/D converters.

Fool-Proof Sensor Measurements

NI CompactDAQ can measure the most common sensor types such as thermocouples, strain gages, and accelerometers in addition to voltage and current. The NI-DAQmx software included with NI Compact DAQ contains DAQ Assistant, a guided wizard utility that automatically scales measured signals into engineering units, such as degrees Celsius for thermocouple measurements. This feature eliminates manual scaling with complex formulas and look-up tables.

Easy PC Connectivity with Hi-Speed USB

USB has greatly simplified PC-based test and measurement. Because USB is a plug-and-play bus, the NI CompactDAQ chassis and all I/O modules are automatically detected and configured when connected to a USB port. Unlike legacy GPIB and serial devices that require an interface board, NI CompactDAQ connects directly to the USB port through a standard USB cable. This cabling feature eliminates another hidden cost associated with traditional instruments. With simple USB cabling, you can easily move an NI CompactDAQ system from one PC to another.

Hi-Speed USB (2.0) provides a 40X increase in bandwidth from the earlier USB 1.1 standard. At 480 Mb/s, it is almost 5X faster than the 100BaseT Ethernet connection on most PCs. Thus NI CompactDAQ has sufficient bandwidth to easily stream data directly to and from the PC rather than buffering it in onboard memory. It also has lower latency times than Ethernet or serial, so commands to and from the PC are transmitted in less time.

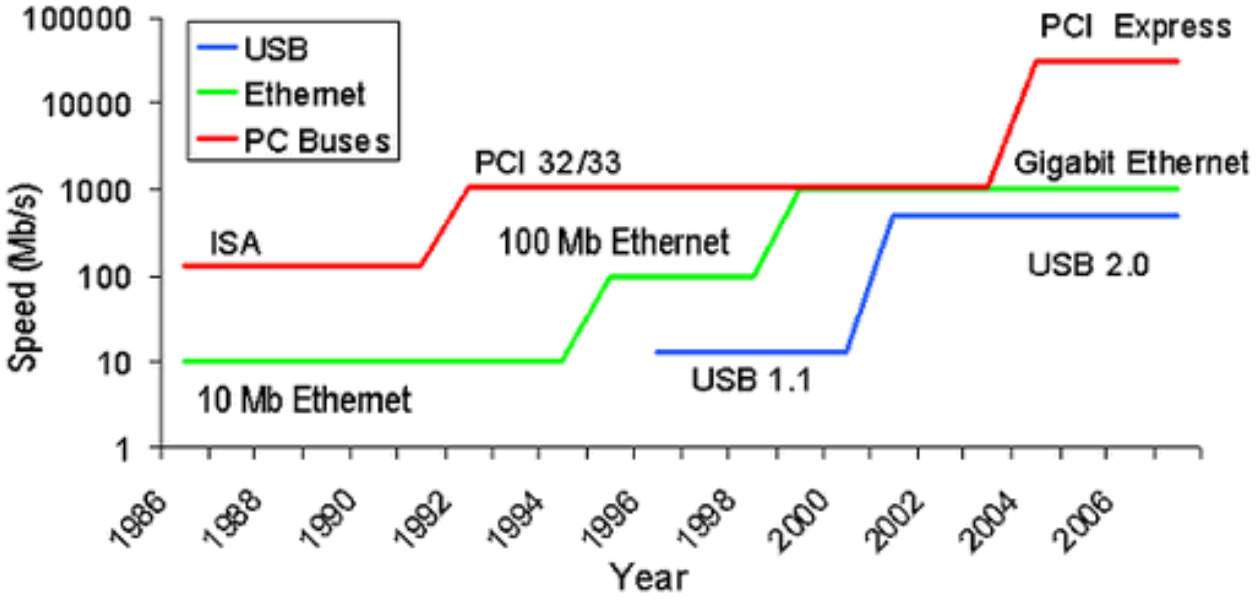


Figure 3. Hi-Speed USB is 40X faster than the preceding USB 1.1, and has 5X the bandwidth of 100 Mb/s Ethernet

Instant Measurements with NI CompactDAQ

Flexible Software – Turnkey Data Logging, LabVIEW, Visual Studio .NET and C/C++

Every NI CompactDAQ chassis is shipped with the FREE data-logging software package, National Instruments LabVIEW SignalExpress LE. With this ready-to-run software, you can acquire data from multiple devices that run NI-DAQmx, and log the data to file or export the data to a spreadsheet. With USB plug-and-play data acquisition and NI LabVIEW SignalExpress, you can connect NI CompactDAQ to a PC or laptop and start measuring data within three clicks of your mouse.

For more advanced data-logging features such as alarming, timed logs, analysis, and reporting, there is LabVIEW SignalExpress, a full-featured nonprogramming development environment that works with all devices that run NI-DAQmx including NI CompactDAQ. See Table 2 for a feature comparison between LabVIEW SignalExpress and LabVIEW SignalExpress LE.

For greater flexibility, NI CompactDAQ also includes NI-DAQmx driver and measurement services software for NI LabVIEW, LabWindows/CVI, C/C++, and Visual Studio .NET. In addition to basic driver functionality, NI-DAQmx includes a configuration management and testing utility, the DAQ Assistant wizard utility, and high-performance features such as multithreading and data compaction. LabVIEW is an industry-leading graphical programming and development environment for designing test, measurement, and control systems. It combines the flexibility of a programming language with built-in tools designed specifically for test, measurement, and control to create applications ranging from simple temperature monitoring to sophisticated control systems.

To learn more about data logging software from National Instruments, see the Three Levels of Data-Logging Software from National Instruments tutorial.

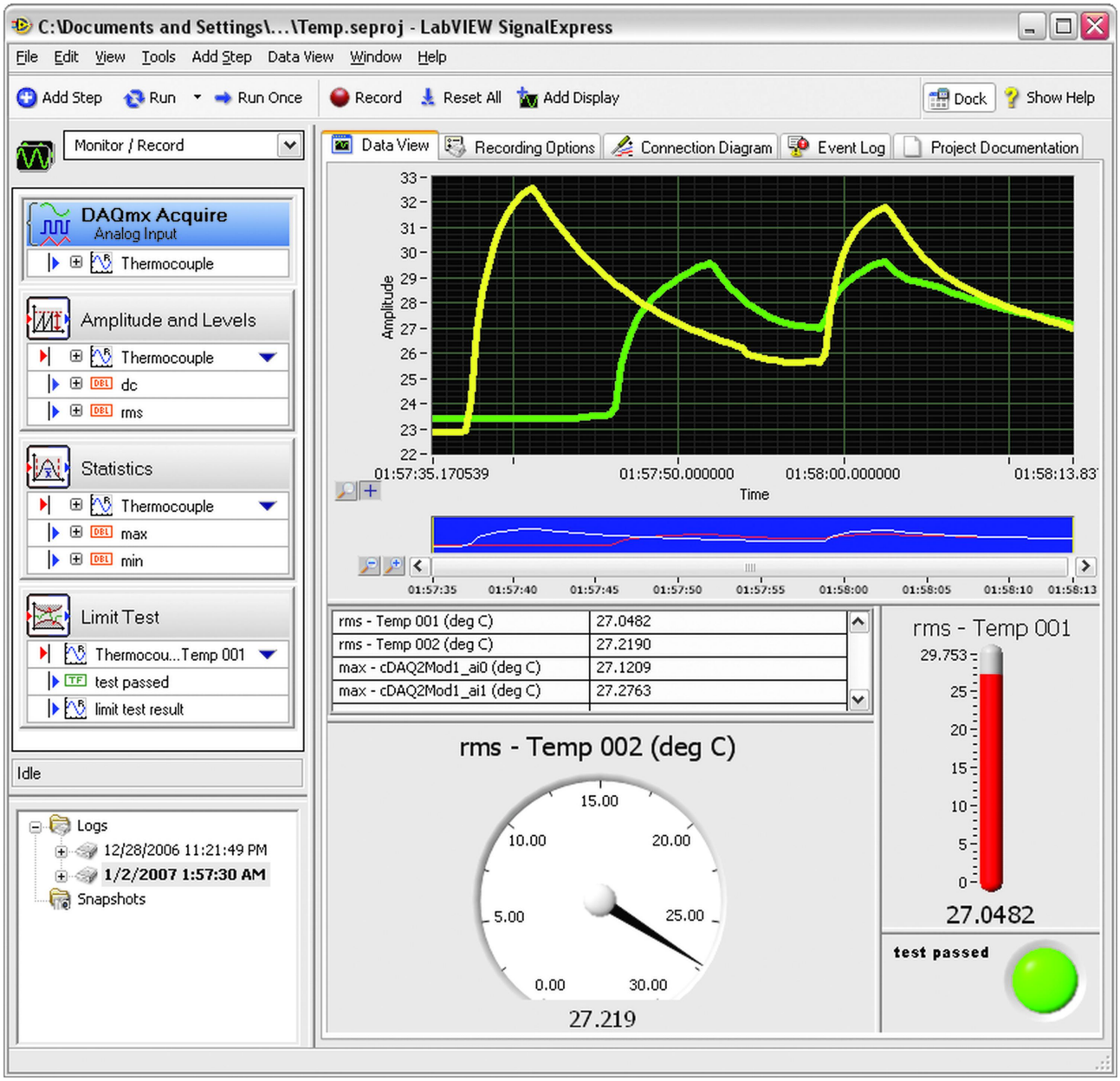


Figure 4. LabVIEW SignalExpress UI (example)

You can directly convert both LabVIEW SignalExpress and LabVIEW SignalExpress LE into LabVIEW graphical code for advanced programming and data acquisition capabilities.

Feature	LabVIEW SignalExpress LE	LabVIEW SignalExpress
Ability to perform simple continuous data logging	#	#

Acquisition from more than one device	#	#
Multiple UI indicators	#	#
Autolaunch for USB devices	#	#
NI-DAQmx support	#	#
Getting started guide	#	#
LabVIEW code generation	#	#
Historical data navigation	#	#
Exportation to Excel or other spreadsheet	#	#
Ability to load saved data	#	#
Multiple log files	#	#
More than 200 analysis functions	#	#
Alarms/triggers	#	#
Dynamic report generation	#	#

Table 2. LabVIEW SignalExpress Comparison

More Channels, Less Space

Benchtop space is valuable, and large data acquisition systems often take up more than their fair share of it. NI CompactDAQ packs up to 256 channels of I/O in a 25 by 9 by 9 cm chassis that weighs less than 1 kg. In fact, a NI CompactDAQ chassis takes up less than 25% of the benchtop space required for a typical box data acquisition system, such as the Agilent 34970.

NI CompactDAQ is ideal for applications that require portability. It fits easily in a laptop bag, and can be powered by DC sources for in-vehicle and other applications where AC wall power is not available.

Figure 5. NI CompactDAQ is shown beside an existing data acquisition system to demonstrate the dramatic size difference.

Improved Safety and Accuracy with Digital Isolation

All but one of the NI CompactDAQ modules (NI 9233) are digitally isolated from the chassis and from other modules. Isolation prevents harmful signals from electrostatic discharge (ESD), lightning, and power surges from damaging the carrier, other modules, and the host PC. Most I/O modules feature up to 2,300 V_{rms} isolation (withstand), and 250 V_{rms} isolation (continuous). Each component comes with a variety of international safety, electromagnetic compatibility (EMC), and environmental certifications and ratings.

Digitally isolated NI CompactDAQ modules also break error-causing ground loops. Ground loops occur when the system or device under test shares the same ground as the data acquisition system and there is a potential difference between the two devices. Because isolated NI CompactDAQ modules do not use the external power connection as a ground reference, the possibility of inaccuracies due to ground loops is eliminated.

Trusted National Instruments Quality

Since 1976, National Instruments has been trusted for reliable products, future compatibility, and quality support. In 2005, customers installed more than 6 million National Instruments measurement channels, and 95% of Fortune 500 manufacturing companies used National Instruments products for test and control.

All NI CompactDAQ systems include a full 1 year warranty on manufacturing defects. Startup and troubleshooting assistance from applications engineers is also available free by Web, e-mail or phone.

Frequently Asked Questions

A consolidated, and growing, list of frequently asked questions can be found at NI CompactDAQ FAQs.

Related Links:

www.ni.com/compactdaq

Out of box "Getting Started with NI CompactDAQ" video

NI CompactDAQ Virtual Tour

NI CompactDAQ Configuration Advisor

Request an NI CompactDAQ On-site Demonstration

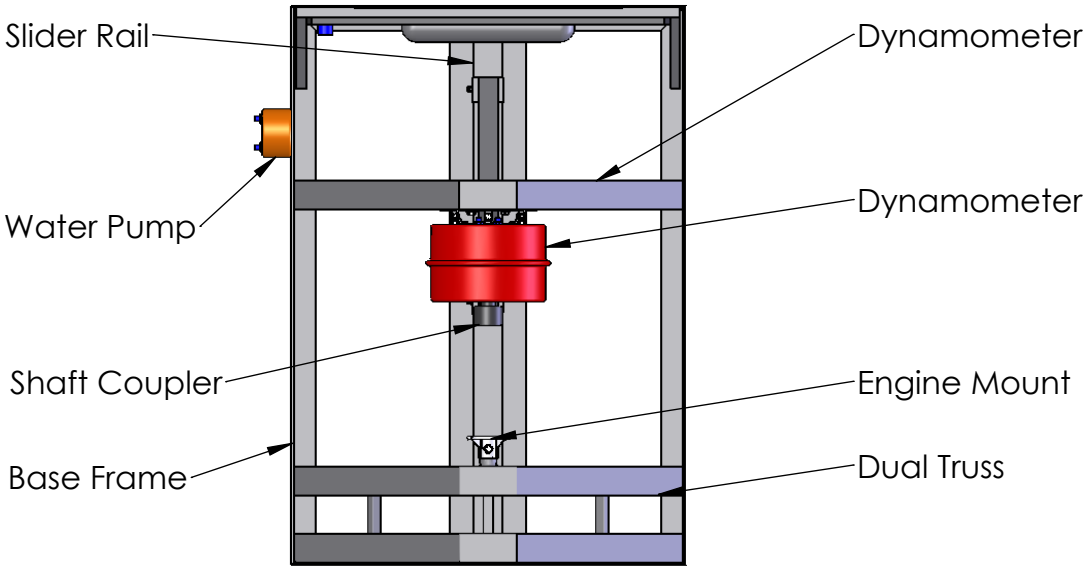
NI CompactDAQ Webcast on Demand

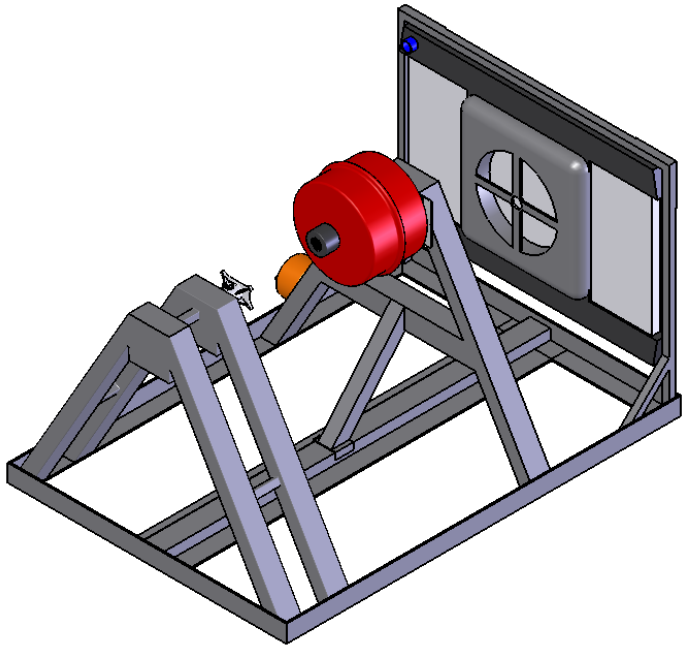
NI CompactDAQ Under the Hood – Three Technologies That Drive USB Performance

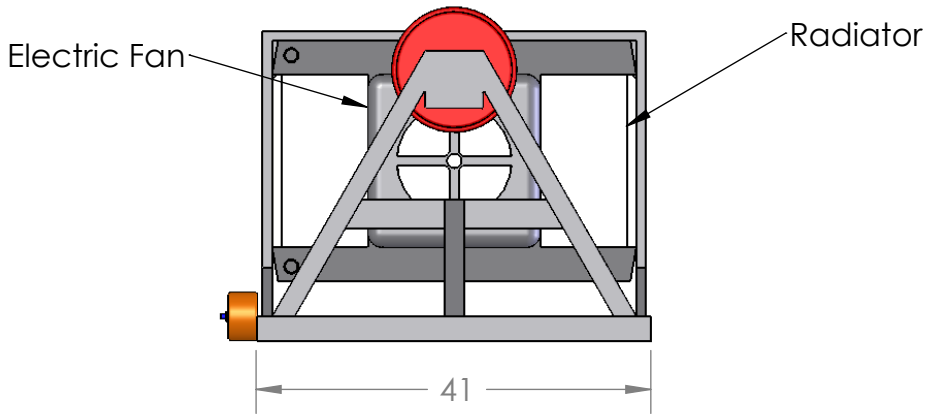
APPENDIX B – ENGINE TEST STAND DRAWINGS

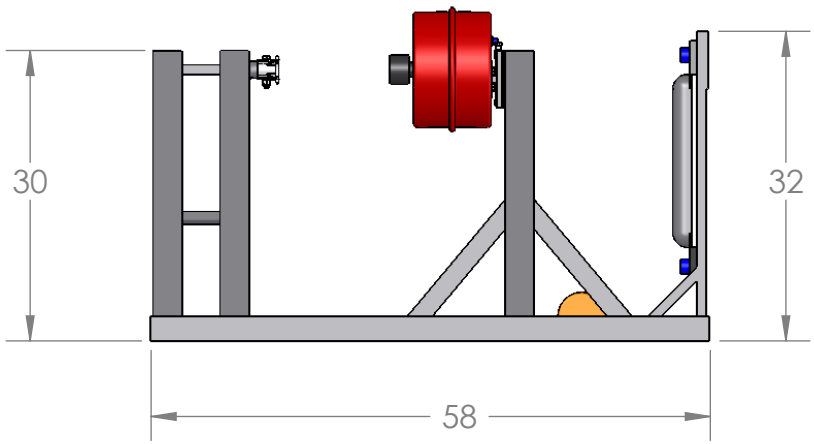
UAV ETS Stand Assembly

(Units are in inches)





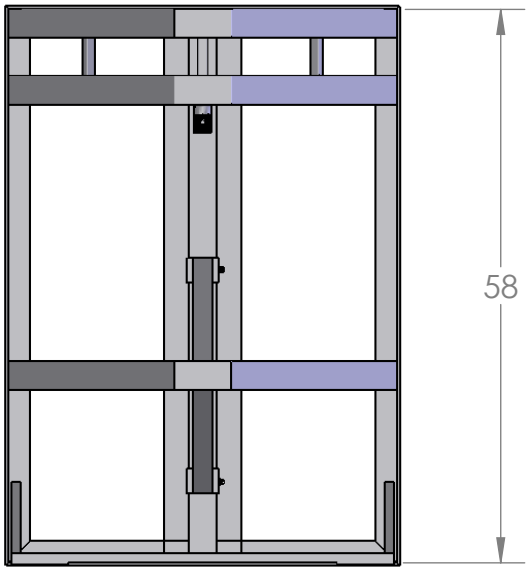


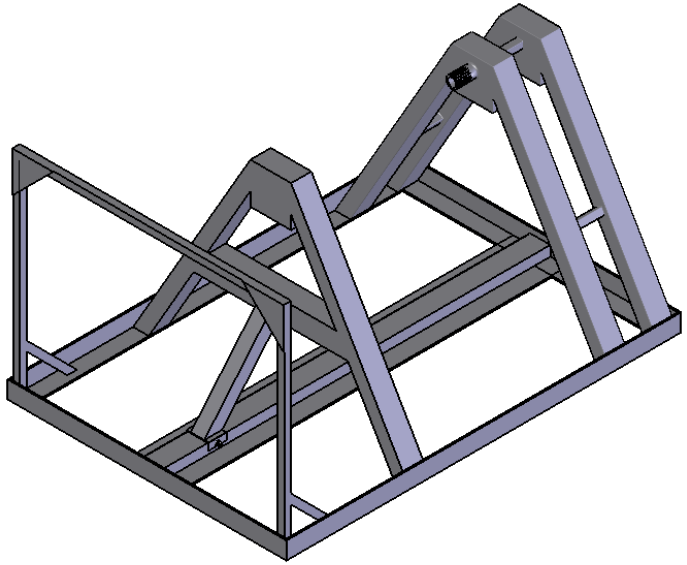


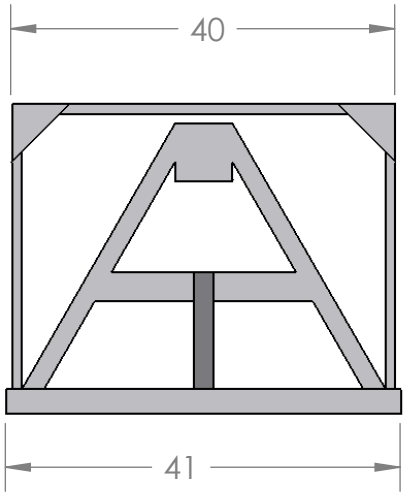
5 4 3 2 1

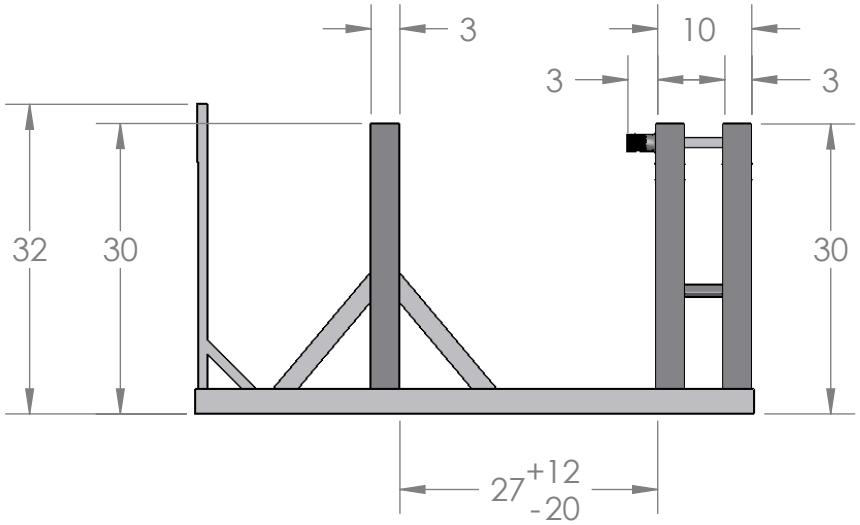
Engine Test Stand

(Units are in inches)



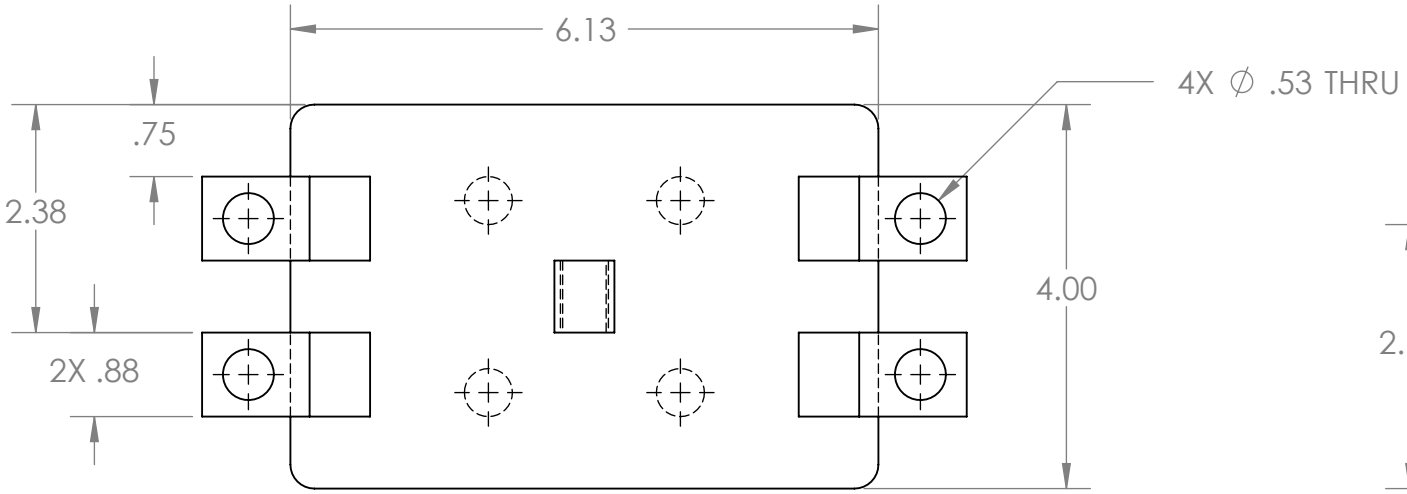


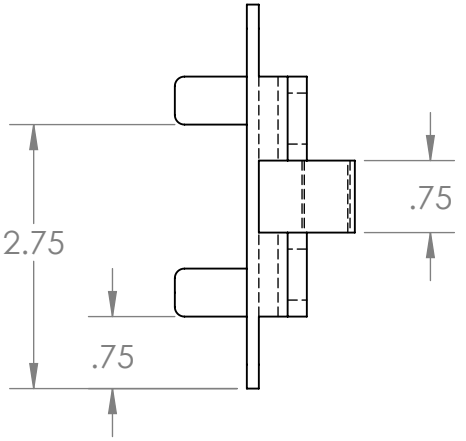


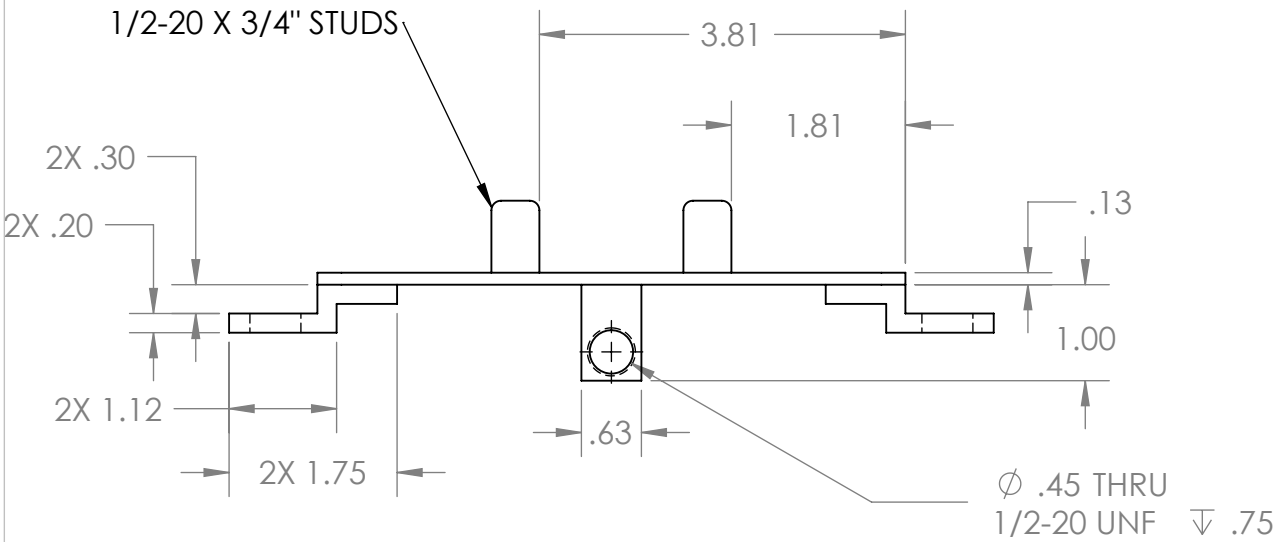


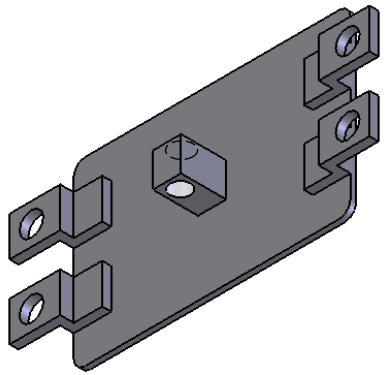
Front Plate, Dynamometer Mount

(UNITS ARE IN INCHES)



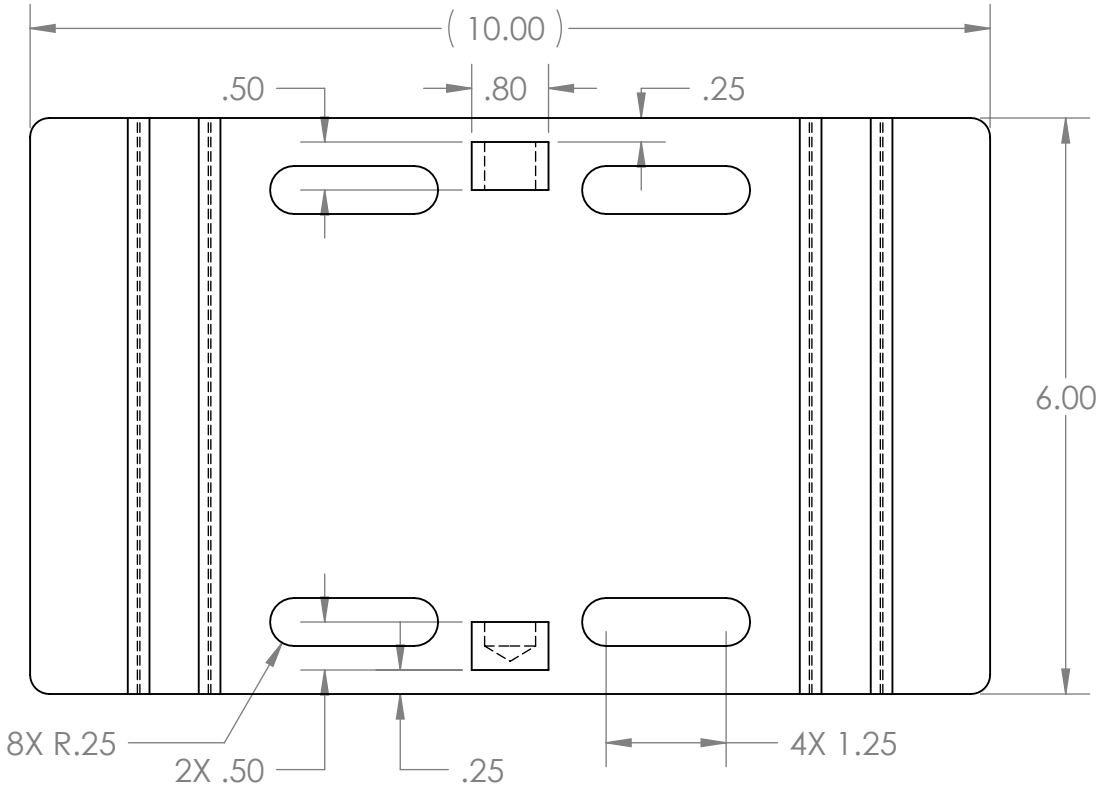


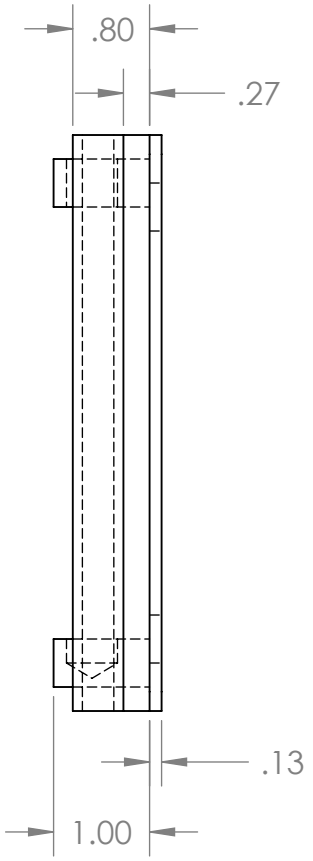


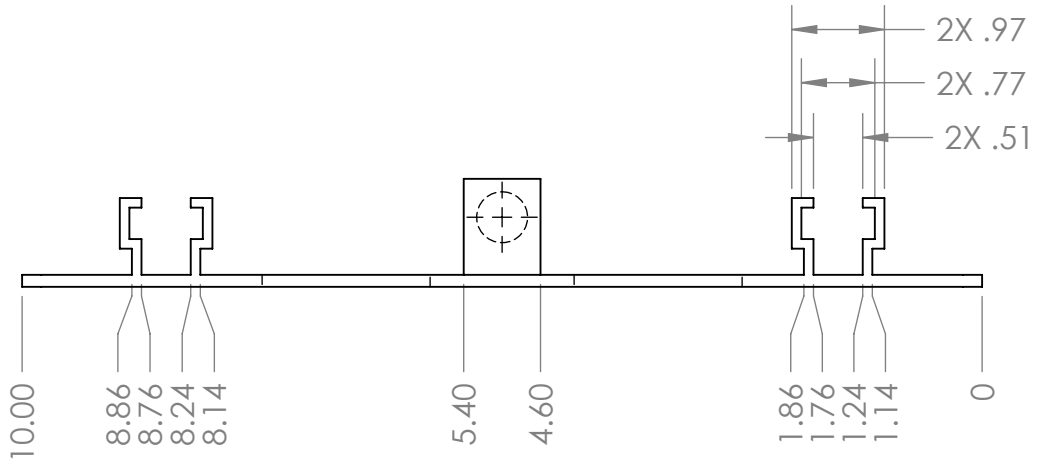


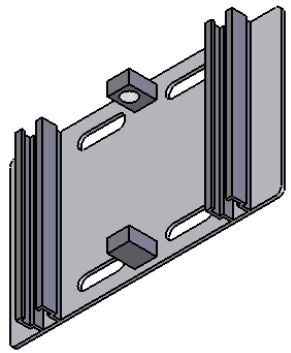
Back Plate, Dynamometer Mount

(Units are in inches)

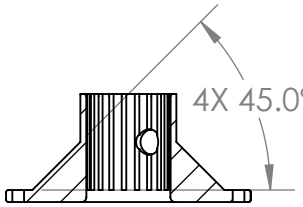




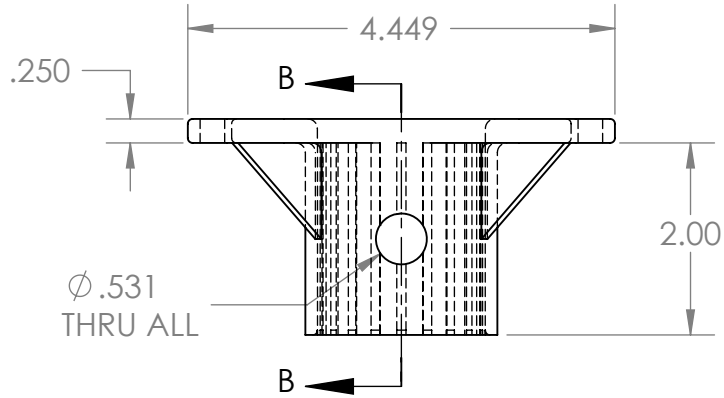


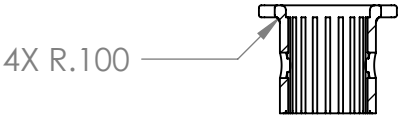


Brent Minchew
29 Feb 2008
Project Unknown

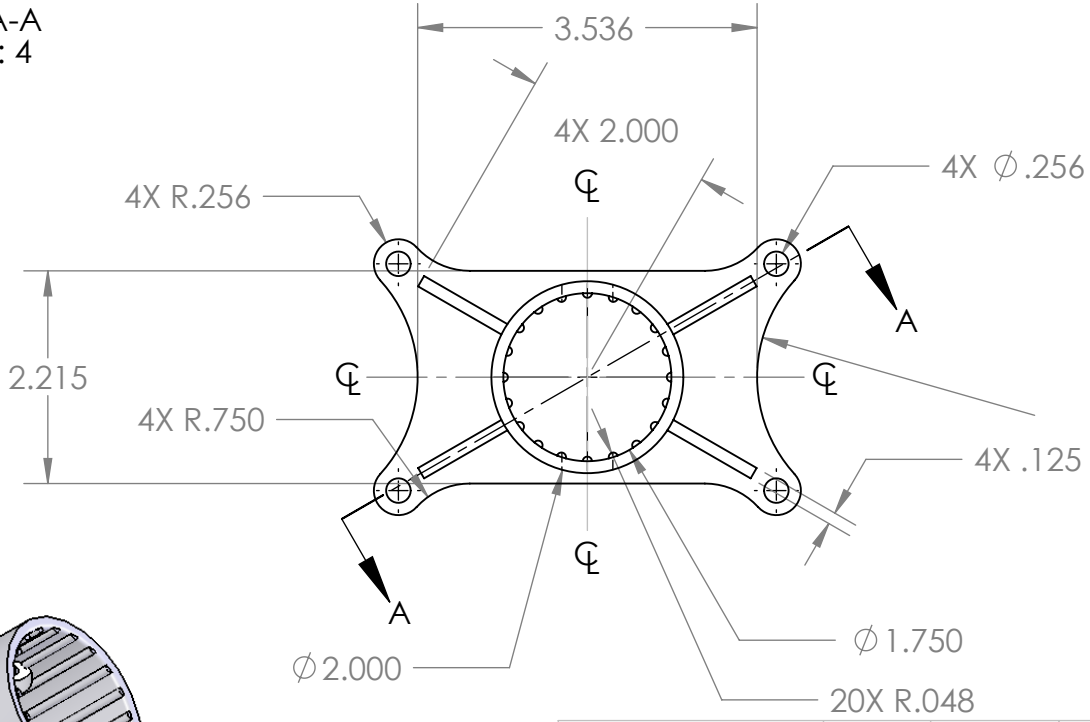


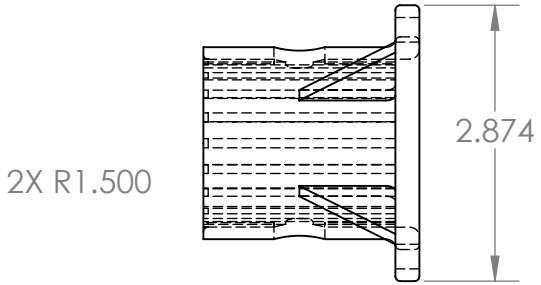
SECTION A-A
SCALE 1 : 4

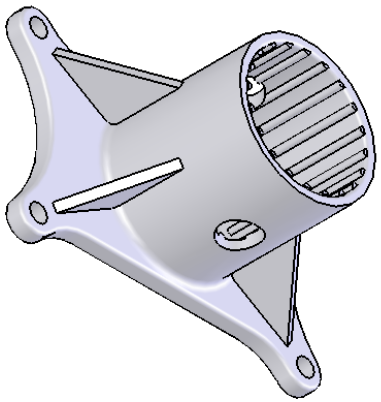




SECTION B-B
SCALE 1 : 4







UNLESS OTHERWISE SPECIFIED:		
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± .05° ONE PLACE DECIMAL ± .015 TWO PLACE DECIMAL ± .010 THREE PLACE DECIMAL ± .005		
INTERPRET GEOMETRIC TOLERANCING PER:		
MATERIAL 4340 STEEL		
FINISH		
DO NOT SCALE DRAWING		

	NAME	DATE
DRAWN	B. MINCHEW	29 FEB 08
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

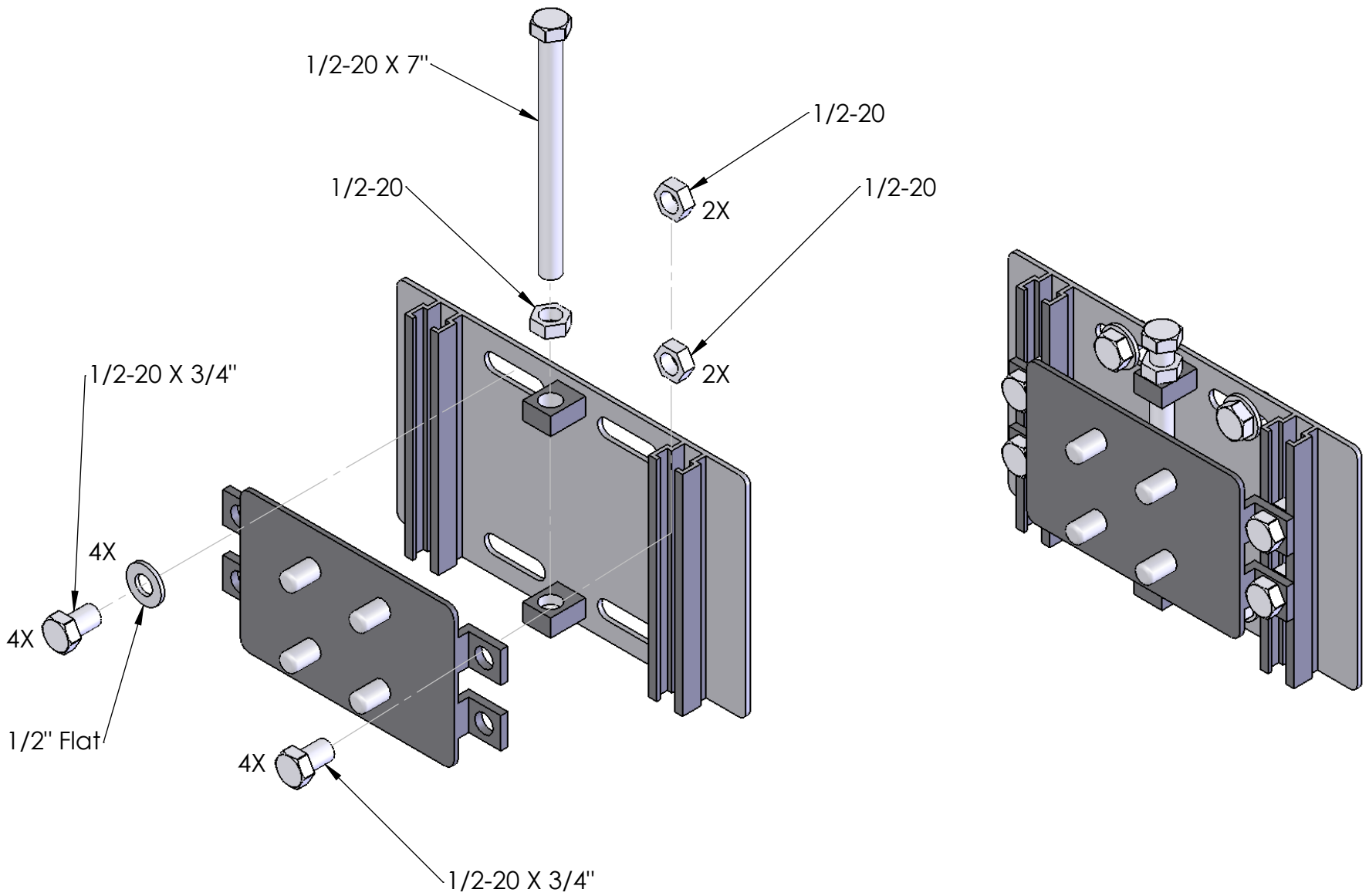
MOUNT, ENGINE, ZANZOTERRA 498

SIZE	DWG. NO.	REV
A		A

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

Dynamometer Mount Assembly



APPENDIX C - SMALL TO MID SIZE UAV ENGINE SPECS

C.1 Limbach L550E

C.2 Rotax 912 ULS/S

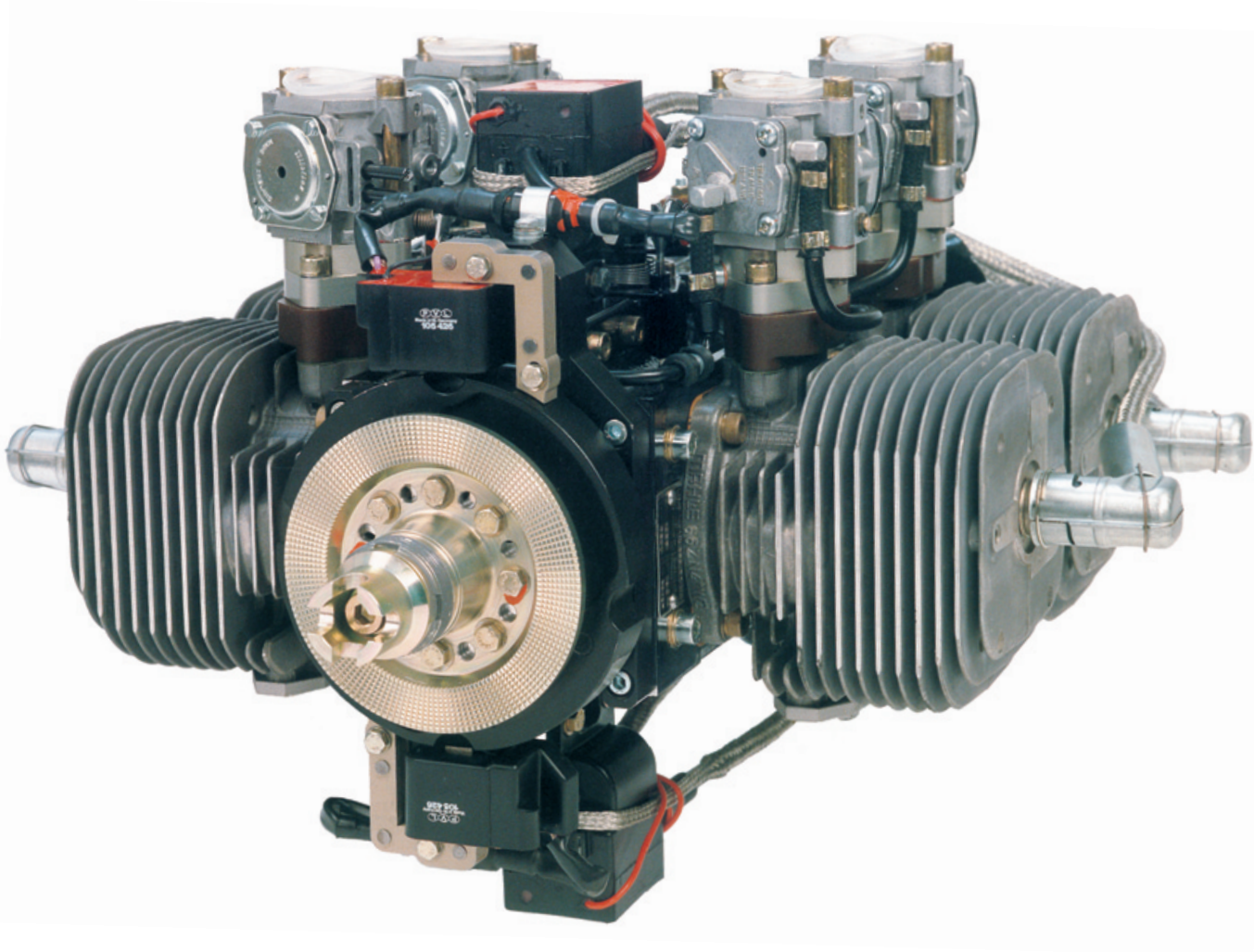
C.3 Rotax 582 Mod 99

C.4 UEL AR801R

C.5 UEL AR741

C.1 Limbach L550E

LIMBACH Flugmotoren



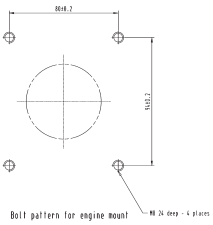
LIMBACH *L 550 E*

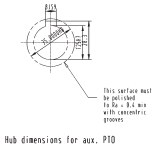
Four cylinder, horizontally opposed, air cooled, two cycle engine, with solid state magneto ignition, mixture lubrication. Suitable for pusher and tractor installations.

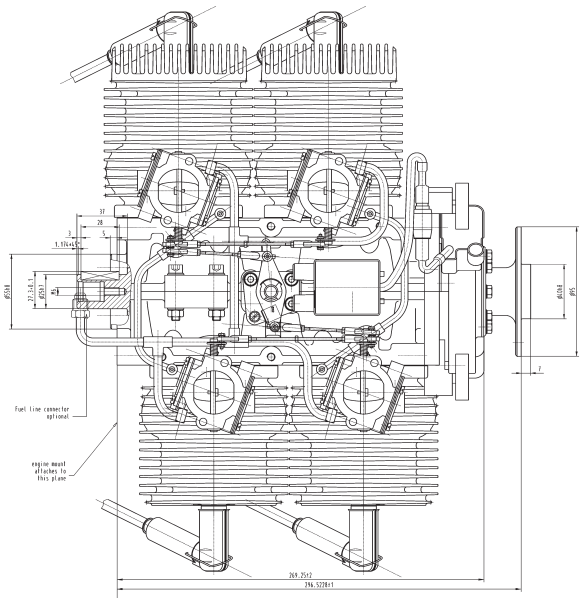
Performance	37 kW (50 HP) at 7500 rpm
Bore	66 mm / 2.60 inch
Stroke	40 mm / 1.57 inch
Displacement	548 cm^3 / 33.44 cub. inches
Crankcase	Aluminum casting
Crankshaft	Drop forged, seven piece
Pistons	Cam ground, casted aluminum alloy
Cylinders	Casted aluminum alloy, with nicasil coated barrel
Ignition system	Solid state magneto ignition
Firing Order	Two opposing cylinders simultaneously, 180 deg. offset
Carburators	4 diaphragm all position carburators
Starter	without
Generator	without
Dry weight approx.	16 kg
Fuel	AVGAS 100LL or 90 RON mixed with a suitable oil to the ratio of 1:25 or 1:50 (with synthetic oil)
Optional Equipment:	Cylinders with additional heat sinks (+ 1.2 kg) Shielded ignition system Exhaust stacks Starter 12/24 V, 0.3 kW Generator 28 V, 1200 W

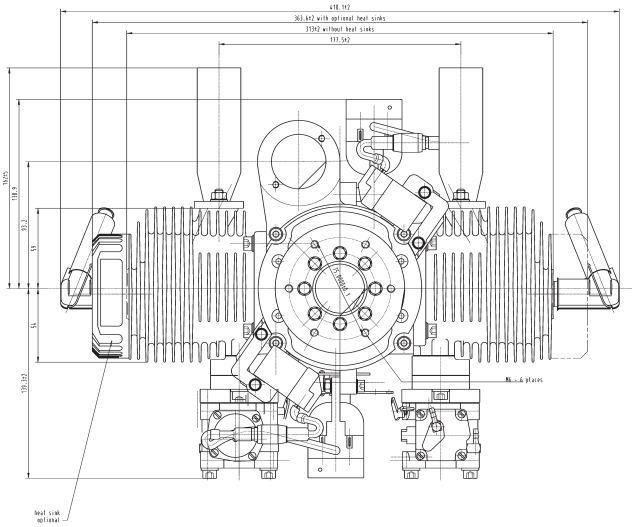
Limbach Flugmotoren GmbH & Co. KG
Kotthausener Straße 5
D-53639 Königswinter-Sassenberg
Tel. ++49-2244/9201-0
Fax ++49-2244/9201-30
E-Mail: sales@limflug.de
www.limflug.de

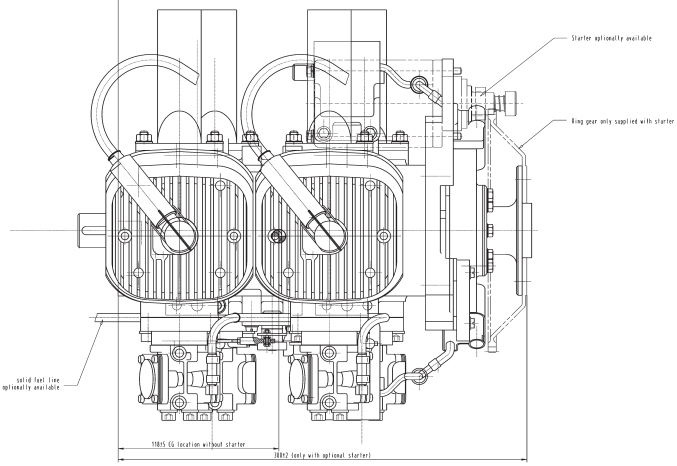
Data may change without prior notice.

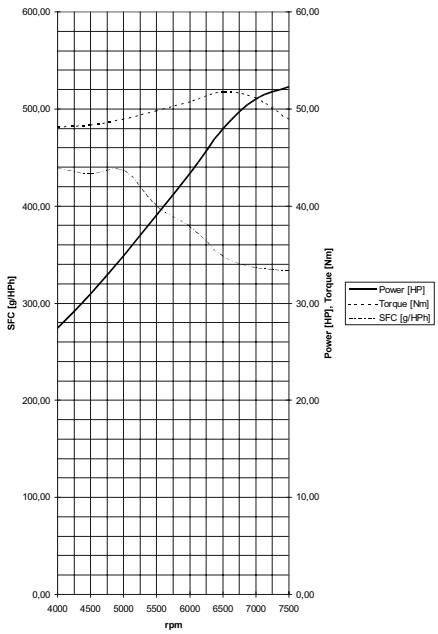












Limbach Flugmotoren GmbH & Co.KG

Kotthausener Straße 5
D-53639 Königswinter-Sassenberg
Tel. ++49-2244/9201-0
Fax ++49-2244/9201-30
E-Mail: sales@limflug.de
www.limflug.de

Data may change without prior notice.

C.2 Rotax 912 ULS/S

C.3 Rotax 582 Mod 99

C.4 UEL AR801R

UAV ENGINES

AR801R - 51 BHP
ROTARY ENGINE FOR UAVs

The AR801R is a tested and proven, light-weight, single rotor, liquid cooled engine with integrated reduction drive. It has been designed and developed specifically for existing and future UAVs requiring 35 to 55 bhp.

DESIGN FEATURES

- Exceptionally high power to weight ratio.
- Reduction drive giving high propeller efficiency.
- Low levels of vibration.
- Economical fuel consumption.

TECHNICAL SPECIFICATION

Engine type:	Single Rotor Wankel-type rotary engine.
Capacity:	Single rotor 294cc.
Power:	40 bhp at 6,000 rpm. Alternatively 51 bhp at 8,000 rpm.
Weight:	56lb (25.4kg) as illustrated, including 2kw generator. Installed weight with cooling system is around 65lb (29.5kg).
Direction of Rotation:	Anti-clockwise (looking at face of prop flange).
Ignition System:	Electronic CD type with magnetic triggering. 12 or 28 volt option. Fully duplicated system firing spark plugs
Fuel Type:	Regular grade (min 92 RON) Mogas (lead or unleaded) or Avgas 100LL.
Specific Fuel Consumption:	0.52lb/bhp hr at 70% cruise = typically 2.0 Imp gallon/hr (2.4 US gall or 9.1 litres).
Vibration:	Nominally zero (± 20cm gm) radial imbalance. Peak-to-mean instantaneous torque fluctuation is 4 approx.
Reduction Drive:	Integrated lightweight belt reduction drive. Standard ratio = 1.93 with alternative ratios in range 1.6 to 2.2.

NOTE

Certain design features of the engine are covered by British, U.S. and other foreign patents.

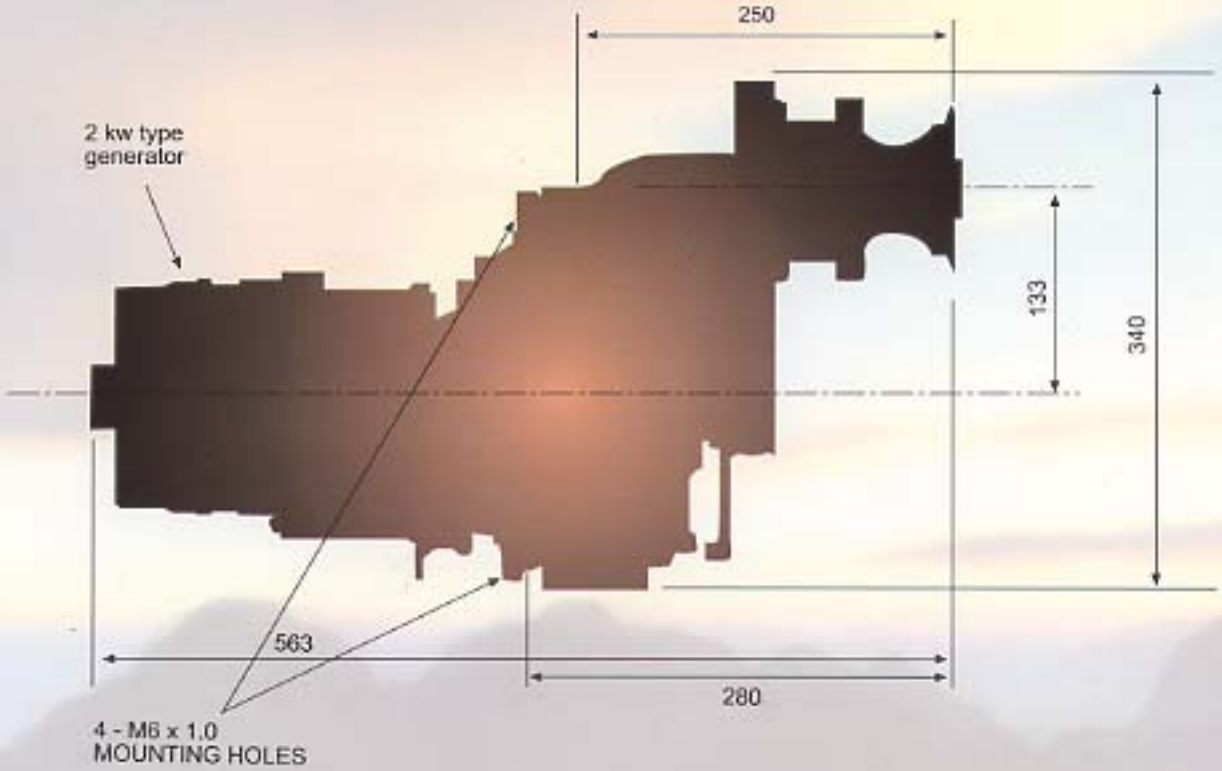
LYNN LANE SHENSTONE
LICHFIELD WS14 0DT
UNITED KINGDOM

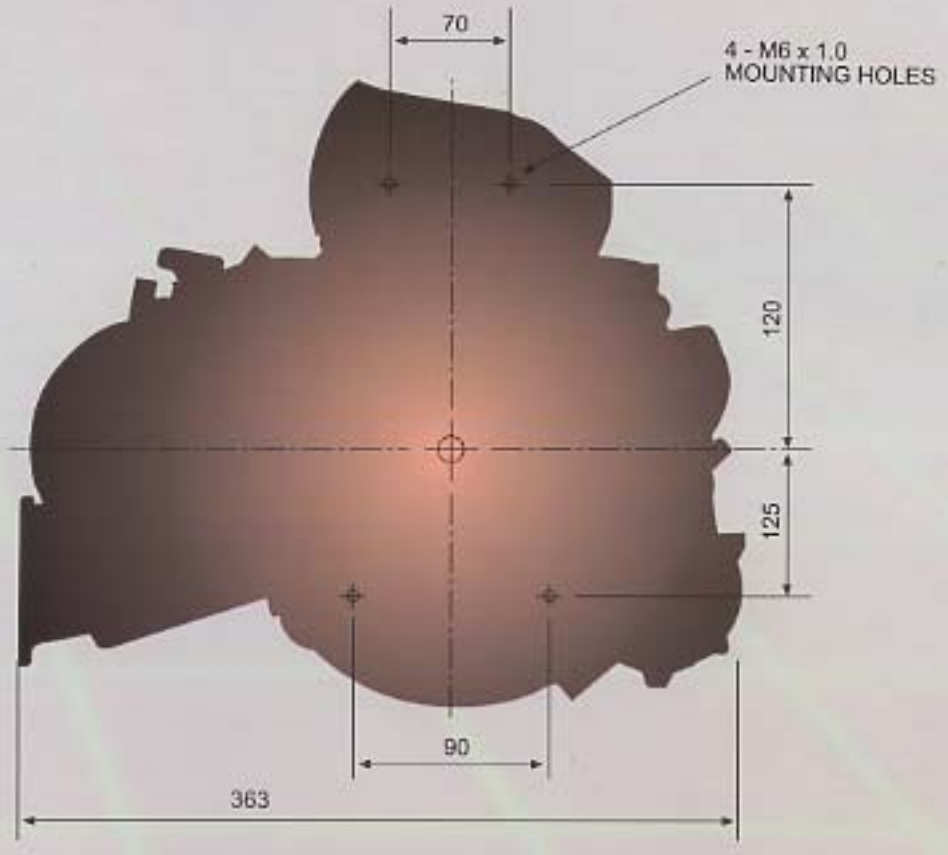
TEL: +44 (0)1543 481819
FAX: +44 (0)1543 481393
info@uavenginesltd.co.uk

www.uavenginesltd.co.uk

AR801R

APPROX. EXTERNAL DIMENSIONS (mm)





C.5 UEL AR741

UAV ENGINES

AR741 - 38 BHP

FOR SMALL SURVEILLANCE UAVs

The AR741 has an outstanding power-to-weight ratio combined with much longer life and better SFC than any alternative engine. It has been developed from the mature AR731 target drone engine to meet the needs of small surveillance-type UAV's. The engine has successfully completed a 150 hour Far-33 type endurance test.

DESIGN FEATURES

- Exceptionally light power-to-weight ratio
- Economical fuel consumption
- Low cross sectional area
- Low levels of vibration
- Long life

TECHNICAL SPECIFICATION

Engine Type:	Single rotor Wankel-type rotary engine
Capacity:	208cc chamber size
Power Output:	38bhp (maximum) at 7,800 rpm
Weight:	23.5lbs (10.7kg) without generator
Fuel Consumption:	0.57 lb/bhp/hr at maximum power, 052 lb/bhp/hr at cruise
Vibration Level:	Zero radial vibration. Peak instantaneous torque is 4 times mean
Ignition System:	Electronic contact-less magneto. RFI suppressed HT system
Generator:	Provision for mounting GEC/Plessey 28 volt, 900 or 1500 watt (or alternatives)

NOTE

Certain design features of the engine are covered by British, U.S. and other foreign patents.

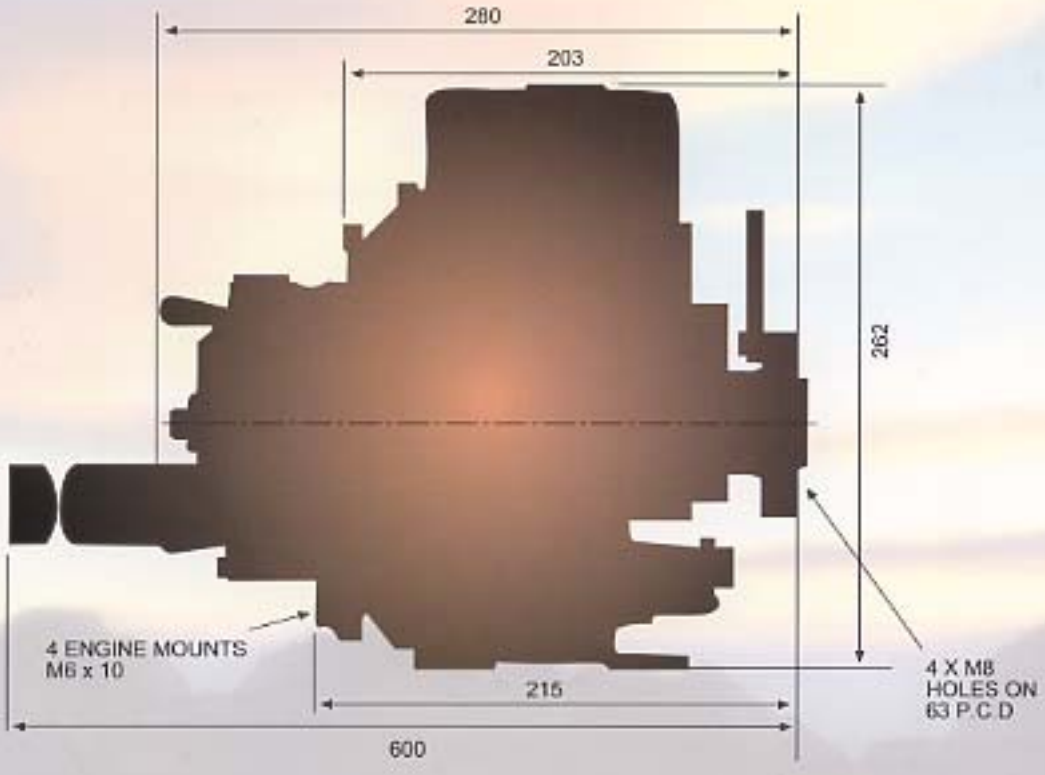
LYNN LANE SHENSTONE
LICHFIELD WS14 0DT
UNITED KINGDOM

TEL: +44 (0)1543 481819
FAX: +44 (0)1543 481393
info@uavenginesltd.co.uk

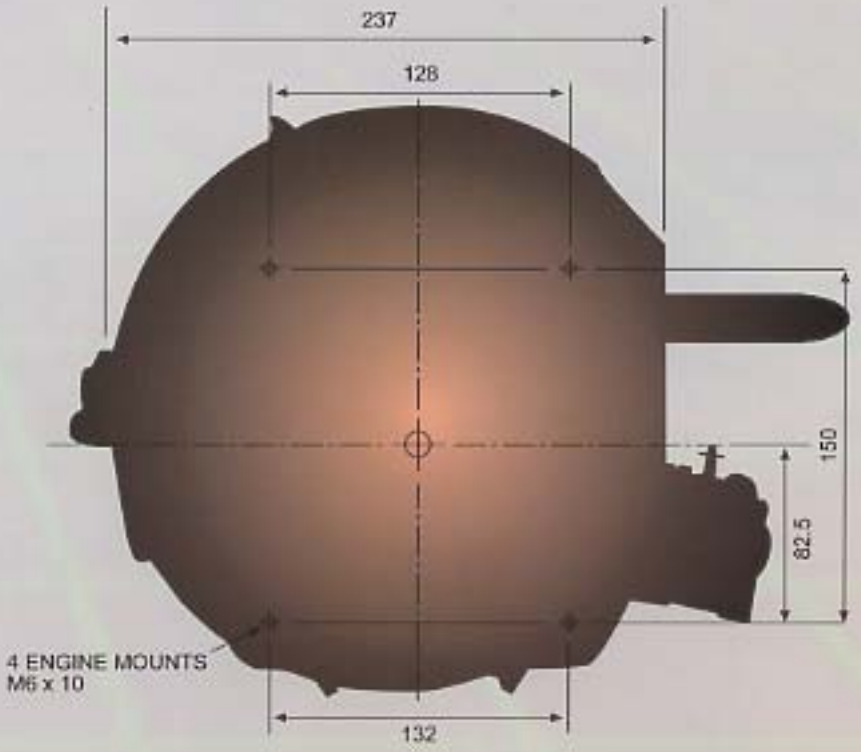
www.uavenginesltd.co.uk

AR741 - ENGINE FOR UAVs

APPROX. EXTERNAL DIMENSIONS (mm)



See installation drawings - 74-1020 for standard pusher version



APPENDIX D – TEST PROCEDURE